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METALS & ALLOYS

Devoted to the Advancement of Scientific Metallurgy

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Comparative Properties of Wrought Iron Made by Hand-Puddling and by the "Aston" Process

H. S. RAWDON and O. A. KNIGHT

X-Ray Metallography in 1929

Part II

PROF. GEORGE L. CLARK

Beryllium

DR. MENAHEM MERLUB-SOBEL

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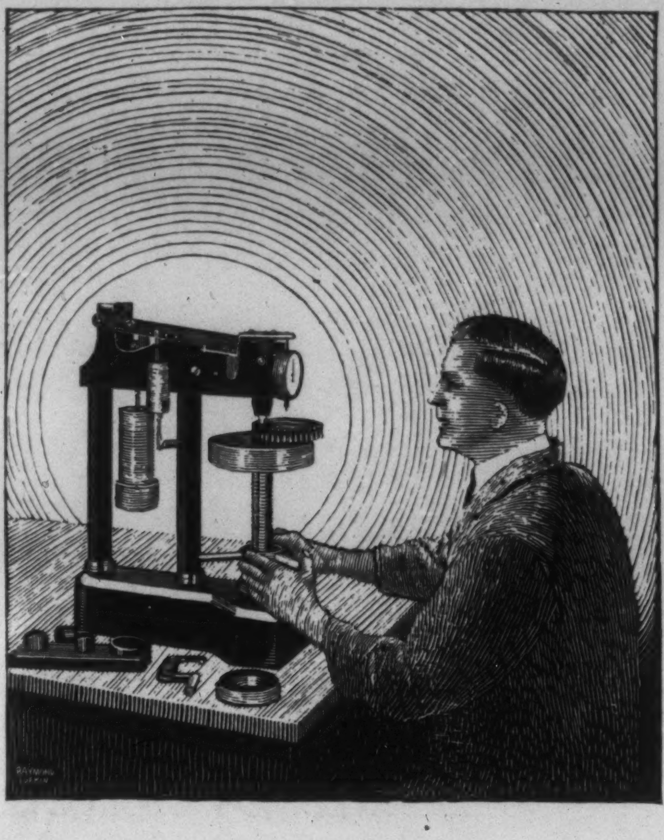

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PUBLISHER'S PAGE

Note—On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

How Do You Like Metals & Alloys?

TO a publisher of periodicals the thrill that comes once or more times in a life-time is when he gets the first copy of Vol. 1 No. 1 of a new paper. His feelings when he picks up the copy to say the least are mingled. What is it going to look like? How many of the cuts will be upside down? And to what extent does the paper as it comes from the printer meet his expectations?

Now that we have told you how the publisher feels when a new paper comes out we would like to know from you just how the subscriber feels, in fact if there were any way of making our 2500 subscribers articulate at this time we would like to hear from every single one.

To what extent have the first two issues met your expectations and needs? When you subscribed for METALS & ALLOYS it was undoubtedly with the idea that this publication would be of direct benefit to you in certain definite and concrete ways. Have we hit the mark in your particular case and if not in what respects have we failed to do so? Which of our departments interests you most and which, if any, would you like to see amplified in future issues? Is the Patent Department of particular interest to you? And are we presenting this material in such form as to meet your requirements?

As we indicated to you on this page last month we are eager to receive suggestions for improving our work as well as criticisms of what we have done. METALS & ALLOYS is dedicated to the advancement of scientific metallurgy. We are following no hard and fast program but shall endeavor rather to make the publication fit the needs of its field as its needs may be disclosed to us by you. We have already received a number of extremely interesting suggestions all of which are being considered and some of which will no doubt be adopted. It will not be possible for us to act upon all suggestions made, but we strongly invite and indeed urge the fullest and frankest expression of opinion at all times. So far as we are able to judge at this writing the first issue has been very well received. It shall be our endeavor with your cooperation to make each succeeding issue of METALS & ALLOYS just a little better and a little more useful than the one that went before. The science which METALS & ALLOYS is striving to serve is advancing with startling rapidity. It shall be our purpose at all times to keep METALS & ALLOYS well in the forefront of metallurgical progress.

So we ask you again, how do you like METALS & ALLOYS? And we hope that you will take time enough to take your pen in hand and tell us exactly how you feel about it.

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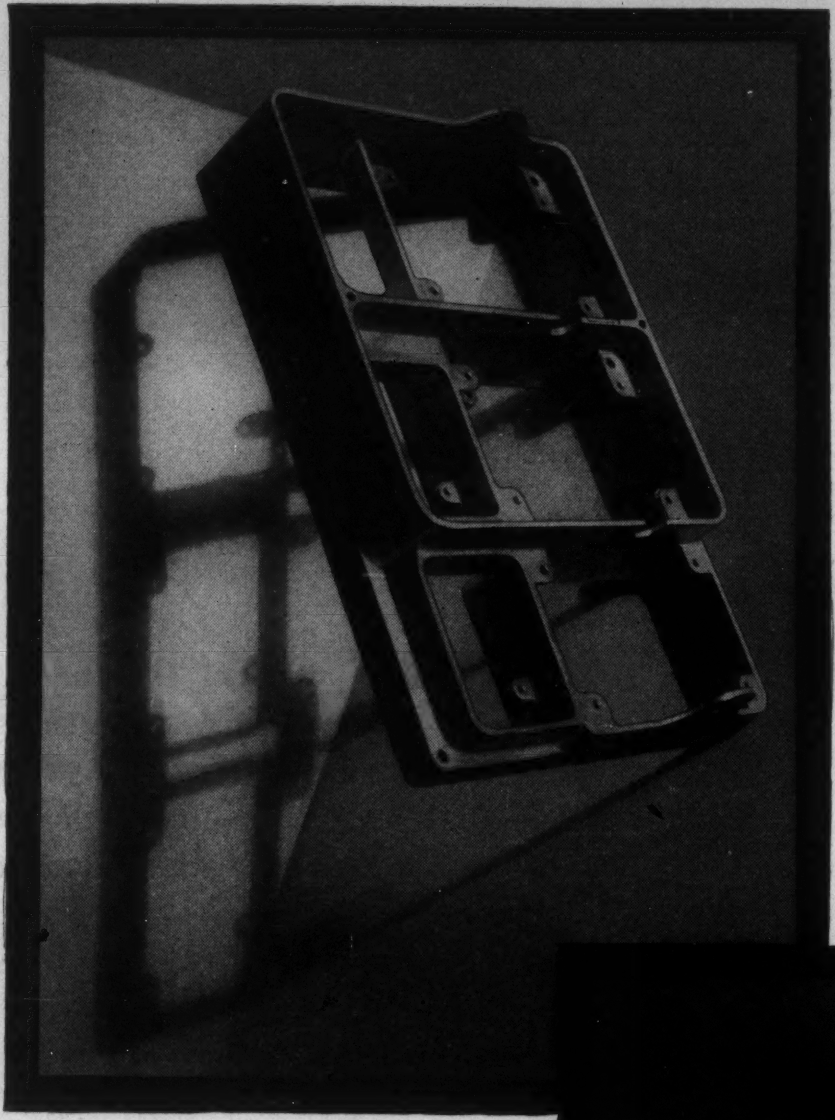

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. GILLETT, *Editorial Director*.

Then and Now

We chanced the other day to leaf over Vol. 7, 1905, of the Transactions of the American Electrochemical Society, and our eye was caught by a sentence in a paper by Carveth and Curry on "Chromium and the Electrolysis of Chromic Acid." After commenting on the fact that there was a great diversity of opinion as to the possibility of depositing chromium from chromic acid solutions, they say, "The selection of such a problem for investigation would by many chemists be regarded as an absolute waste of time."

Nowadays, when nine out of ten taxicabs in New York have chromium plated radiators, and chromium plating is so common and so much discussed, it is something of a shock to hark back to the time when chemists "knew" that chromium could not be plated, just as we now "know" that aluminum cannot be plated from aqueous solutions.

Way back in 1856 Geuther obtained weighable deposits of chromium, but Buff tried it in 1857 and was unsuccessful and promptly broke into print, politely calling Geuther a chemical liar, and after some discussion back and forth Guether's work was pretty much discredited. Although Placet and Bonnet patented the deposition of chromium from chromic acid in 1894, Le Blanc and other chemists of standing were unable to deposit the metal and until the time of Carveth and Curry its deposition was uniformly classed as "impossible." Carveth and Curry proved that it could be deposited and say, "Platings made without stirring the solution and without finishing by buffing, etc., resemble the very finest work done with silver. In fact, for plating purposes the metal should have a great future before it."

The future was somewhat delayed, although Prof. Bancroft had faith in it and put Sargent to work at Cornell in carrying further the work of Carveth and Curry. In 1912 Sargent was making very fine deposits and the properties of the chromium plate, as well as how to plate it, were well understood.

Manufacturers who were approached with the suggestion that they use chromium plating were apathetic. They doubted if the "cold" appearance of the plating would be as attractive to the public as the "warmer" or yellower nickel. In those days people enjoyed using metal polish on the headlights and fittings of the few automobiles that were operating, probably on the same principle that the bright-work of a yacht is cared for. Neat little bags with drawstrings were supplied to slip over the headlights when the car was not in use, to keep the brass from tarnishing.

People either got lazier or their opinion changed as to what constituted a good-looking finish on metal parts before chromium plating became popular. When it did become the style, of course all the automobile makers followed like a flock of sheep.

One might draw several lessons from this chromium plating "golden text." One is that "fundamental" research will be profitable to somebody, sometime. Another is that even though a process and a worthy product may be all worked out, the time may not be ripe for any widespread utilization of the product.

One wonders how many chemical and metallurgical "facts" taught the undergraduates of to-day are as untrue as the "fact" that chromium cannot be plated, and how many new products are waiting for the psychological moment when they will begin to find use.

"Keeping Up with the Jones" at Technical Society Meetings

The older men of any group are prone to forget that in time their places will be taken by to-day's youngsters. The men who fifteen years hence will be bearing the brunt of the work of the technical societies and their committees are just joining those societies to-day.

These youngsters, who are just finishing college or are in the first job, join the societies because they feel that the membership will help them professionally. Very often the membership is not paid for by the firm but comes out of the man's own pocket as an investment in his personal future. Most such men have invested about all they can stand when they have joined the societies that cover their professional field, and they can only manage a trip to a convention if it happens to be in or very near their own home town.

Yet the knowledge they would get by attending the meetings, listening to and modestly entering into the discussions, and, above all, the inspiration they would get by meeting the older men, the leaders of their profession, would make attendance a good investment for the youngsters.

But how often do the officers of the society or the local committees of arrangements consider these men to whom a difference of a few dollars in the minimum necessary expenses at the convention means much? Registration fees to provide "entertainment," costly banquets and the like mount up, and every convention has to outdo the last one, or that of a sister society. The men who plan these functions, if they think of the matter at all, think that a few dollars extra make no difference as it all goes on the expense account of those who attend, anyhow.

But many a youngster who has no expense account, and has not yet established himself on such a footing that he is sent to the meeting but has to go on his own time and at his own expense, would go, and reap the benefits of the contacts he would make, if it were not quite so costly.

There are, too, more mature men, in government service, who may be allowed to travel to meetings that further their work for Uncle Sam, but whose expense accounts must run under a very modest maximum, and in such accounts a "registration fee" or a smoker ticket would not pass the auditor. These men, who are on modest salaries at best, have to pay their own dues for society memberships, and often their own traveling expenses when they do attend the meetings.

Even the men whose expenses are borne by their employers would often welcome greater simplicity in "entertainment" and dinners. They would be just as happy if they did not have to listen to some paid entertainers and if they had one or two fewer courses at the annual banquet.

The impecunious youngster, for example, to whom attendance at a convention is an event to-day, has enthusiasm and professional interest that makes him of potential value to the society as a worker on committees. It is wise to catch him and put him to work before that enthusiasm wears off and convention attendance and committee work become boring.

A scaling down of the cost of convention attendance, the waiving of registration fees for younger men and a general attitude of thoughtfulness for those who do not have expense accounts might, in the long run, be a good investment for our technical societies.

Comparative Properties of Wrought Iron Made by Hand-Puddling and by "Aston" Process*

By H. S. Rawdon[1] and O. A. Knight[2]

Introduction

The need for more economical methods in the manufacture of wrought iron has long been recognized. Aston[3] states the outstanding needs of the wrought iron industry to be: decreased cost of production and increased tonnage, the former being the more essential of the two. These needs have long been realized. Shortly after the advent of the Bessemer steel process attempts were made[4] to increase the scale of production of wrought iron and these have continued to the present, some of the processes developed being used commercially with considerable success. Practically all, with one exception, which have attained any degree of prominence, attempted to duplicate mechanically the operations of hand-puddling, generally by means of a movable furnace. The characteristic features of mechanical puddling processes have been described in the technical literature,[5] and further reference to them is unnecessary. A few years ago, a series of comparative tests was made by the Bureau of Standards of wrought iron prepared by one of these processes (reference "c") together with wrought iron made by the same company by hand-puddling from pig iron of the same heat. One of the conclusions expressed as a result of these tests[6] was as follows: "The tests of two lots of wrought iron made by two distinctly different puddling processes have not shown anything to indicate that the hand-puddled product cannot be equaled in an iron made by a mechanical puddling process."

About a year ago, the attention of the Bureau of Standards was directed to the successful commercial development of a very novel process for the production of wrought iron which appears to possess the essential characteristics usually associated with the time-honored product of hand-puddling. The new process differs radically in many respects from the conventional method of puddling. In this process, referred to hereinafter as the "Aston process," the essential objects of the puddling process, as ordinarily understood, are attained in a unique manner. The melting of the raw material, pig iron, is done in a cupola, the refining of the molten metal in a Bessemer converter, the production of the slag of proper composition in an open-hearth furnace by itself and the mechanical disintegration of the iron and the incorporation of the slag with it are attained by pouring the molten iron into the molten slag. The squeezing of the "ball" involves no new principle, nor does the subsequent mechanical working of the iron.

Details of this process have already been published.[7] As a convenient means of summarizing in concise form the essential features of the process, however, so as to obviate reference to the published descriptions, Figures 1 and 2 are given below. Some details concerning compositions and the like taken from the mill records of the manufacturers, the A. M. Byers Company, are also given.

This process has definitely passed the experimental stage and the product is now being produced on a tonnage basis, practically all of it being used in the manufacture of pipe. The United States Government is a purchaser of large amounts of wrought iron and has drawn up specifications[8] covering wrought iron pipe. In view of this, therefore, together with the interest of the Bureau of Standards in obtaining information on new industrial processes, a study of this material by the Bureau was deemed proper and desirable. The study was undertaken on the Research Associate plan,[9] the investigator appointed for

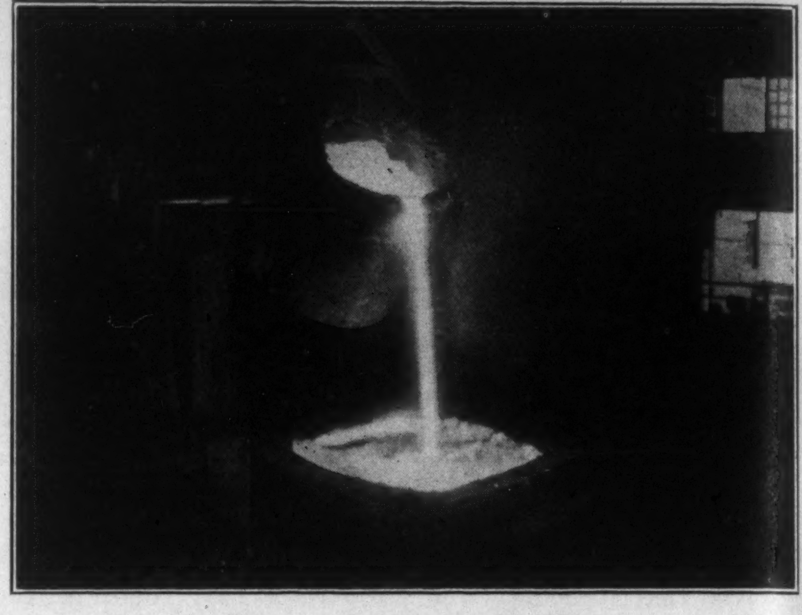

Figure 1—The Shotting Operation

The metal in the tilted ladle has just come from the Bessemer converter where it has been "blown." Note the surface of the slag in the lower container, the shotting cup, which nearly reaches the top of the cup on account of the vigorous gas evolution produced by pouring the molten metal into the molten slag

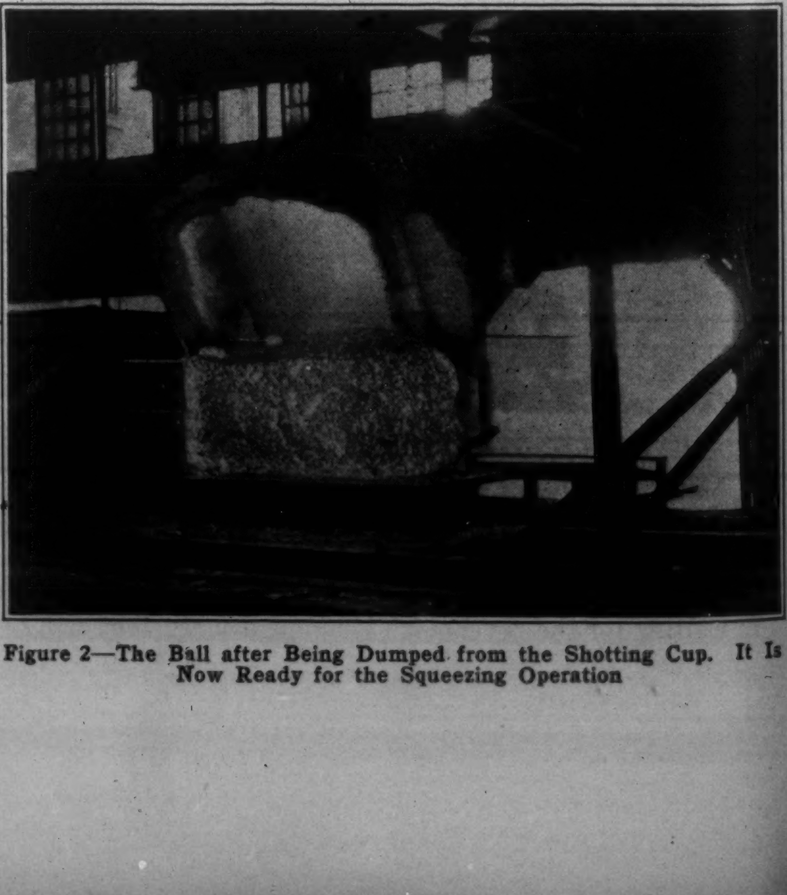

Figure 2—The Ball after Being Dumped from the Shotting Cup. It Is Now Ready for the Squeezing Operation

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* Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[1] Senior Metallurgist, Bureau of Standards.

[2] Associate Professor of Metallurgy, Pennsylvania State College. Research Associate (1928), Bureau of Standards.

[3] James Aston, "Trend of Development in the Wrought Iron Industry," Amer. Inst. Min. Met. Eng., *Pamphlet* **No. 1595-C,** October, 1926.

[4] Thomas Turner, "Metallurgy of Iron," 5th ed., p. 387, Chas. Griffin & Co. (1918).

[5] Symposium on Wrought Iron: (*a*) H. E. Smith, "Manufacture and Use of Wrought Iron;" (*b*) F. H. Dechant, "Ely Process of Mechanical Puddling for the Production of Wrought Iron;" (*c*) J. P. Roe, "Roe Puddling Machine;" (*d*) James Aston, "Problem of Wrought Iron Manufacture and a New Process for Its Production," American Iron & Steel Inst., *Yearbook,* **15,** 117 (1925). See also footnote 3.

[6] Henry S. Rawdon and Samuel Epstein, "Observations on Phosphorus in Wrought Iron Made by Different Puddling Processes," Amer. Iron & Steel Inst., *Yearbook,* **16,** 117 (1926).

[7] See footnote 3, also reference (*d*), footnote 5.

[8] Federal Specifications Board, Specification 242, Pipe, Wrought Iron, 1925.

[9] Bureau of Standards, *Circular* **No. 296,** Research Associates at the Bureau of Standards.

carrying out the work being O. A. Knight, Associate Professor of Metallurgy, Pennsylvania State College. The work was supported by the A. M. Byers Co., the manufacturers.

Résumé of the Aston Process

The process differs from puddling, as ordinarily understood, in that the various objects to be accomplished are brought about as distinct steps separately, instead of as a single-furnace process, the nature of which gradually changes as it proceeds. The description as given below is based upon mill observations and represents the practice at the time the observations were made, though not necessarily so, in all details, as carried out at present. Standard cupola melting practice was followed in melting the pig iron (Bessemer grade). Mention should be made, however, of the soda-ash treatment of the molten metal to offset sulphur "pick up." About 40 to 50 lbs. of soda ash was placed in the ladle into which a charge of approximately 5500 lbs. was tapped from the cupola. About 15 minutes was required for the metal to flow and this insured thorough mixing and plenty of time for the desulphurizing reactions to occur. The ladle metal was then skimmed free from slag and charged into the Bessemer converter. Table 1 shows the composition after this treatment.

A 2-ton side-blow converter was used, the "blow" usually lasting about 18 minutes. The composition of the blown metal is given in Table 1. The blown metal was tapped into a lip-pour ladle and the slag raked off. No additions of manganese, silicon, aluminum or other deoxidizing or degasifying agents such as are used in steel manufacture were employed. The metal was "shotted" in the condition as teemed from the converter.

The shotting operation was as follows: (1) molten slag was poured into one of the "shotting cups" until it was about two-thirds filled, (2) the ladle of blown metal was then moved up to this cup and (3) molten metal was poured slowly into the slag at a rate of about one ton in three minutes (Figure 1). One ladle of blown metal furnished two balls, each weighing between 2200 and 2500 pounds. The height of the lip of the ladle above the slag surface in the cup was about 9 ft. The temperature of the molten slag must be maintained considerably below that of the molten iron which is to be poured into it. If no precautions were taken the temperature of the slag might rise sufficiently, as a result of the heat liberated by the iron as it passes from the liquid state upon quenching, to interfere seriously with the efficacy of the slag as a quenching medium. Any undue rise of temperature of the slag was prevented by throwing a shovelful of cold granulated slag into the shotting cup from time to time. This also served to prevent "boiling over" of the slag in the cup which might otherwise occur as a result of the vigorous gas evolution which takes place when the stream of molten metal is poured into the molten slag. The boiling subsided quickly as soon as the last of the molten metal had been poured and, when quiet, the cup was about two-thirds full. The excess slag was then decanted from the cup containing the shotted metal into the cup which was to be used next, and the "ball" was then dumped on to a carriage (Figure 2), and was ready to be taken to the press.

The slag was prepared in a 15-ton tilting open hearth furnace, the composition being maintained as close as practicable to the average composition of that which is formed in ordinary puddling (Table 2). The effect of the shotting operation evidently depends mainly upon the difference in temperature between metal and slag and the gas evolution which occurs as the two materials are brought together. Previous mill observations had shown that the temperature of the molten slag ~~within~~ the cup was approximately 1315° C. (2400° F.) and that of the molten metal, approximately 1540 to 1590° C. (2800–2900° F.) The violent evolution of gas which occurs as the metal is chilled by the slag comminutes the metal to a relatively fine state of division, thus facilitating the incorporation of the slag within the metal. The particles of metal accumulate in the lower part of the cup and agglomerate into a coherent, spongy mass or "ball" resembling in most essential respects, except size, that taken from the puddling furnaces. The loss of slag is small, the true loss being that which is carried away in the iron.

A fairly compact bloom measuring approximately 12 by 14 inches by 5 feet was produced by squeezing the ball. In the rolling mill, it was given nine passes in a 29-inch mill and seven in a 24-inch mill which reduced it to the form of muck bar $^{3}/_{4}$ inch thick by 8 inches wide, the composition of which is given in Table 1.

Purpose and Scope of the Investigated

Iron made by this process is now a commercial product, and is used in the same manner as, and for the same purpose as, the product of the older and the more familiar hand-puddling process.

The matter of the definition of wrought iron, that is, whether this material should be defined mainly in terms of the process by which it has been produced or by the properties which it possesses is of very considerable importance in the preparation of specifications. In this investigation, however, it was considered that a determination of the properties of the new wrought iron, particularly as compared with those of wrought

Table 1—Results of Chemical Analysis of Metal at Different Stages of Process[a]

Cupola Iron [b]					"Blown" Metal [b]					Wrought Iron—Muck Bar [b]					
Before Soda Ash Addition	After Soda Ash Addition														
S	Mn	S	P	Si	C	Mn	S	P	Si	C	Mn	S	P	Si	Slag and Oxides [c]
0.072	0.56	0.039	0.098	1.44	0.08	0.02	0.048	0.100	0.026	0.02	0.03	0.031	0.100	0.122	2.46
0.057	0.49	0.039	0.103	1.02	0.07	0.04	0.040	0.103	0.028	0.03	0.04	0.027	0.097	0.132	4.17
0.083	..	0.044	...	1.09	0.06	..	0.057	...	0.015	0.03	0.03	0.037	0.118	0.103	2.98
0.127	..	0.044	...	1.14	0.06	..	...	...	0.010	0.02	0.03	0.042	0.112	0.132	3.53
0.098	..	0.048	...	1.13	0.07	..	0.051	...	0.014	0.03	0.05	0.042	0.130	0.190	4.25
0.088	..	0.056	...	1.19	0.06	..	0.060	...	0.011	0.03	0.04	0.043	0.126	0.202	4.30
0.111	..	0.050	...	1.18	0.06	..	0.060	...	0.017	0.03	0.04	0.038	0.120	0.132	3.12
0.084	..	0.040	...	0.99	0.07	..	0.046	...	0.010	0.03	0.04	0.037	0.120	0.121	3.08
0.079	..	0.040	...	0.93	0.08	..	0.048	...	0.008	0.03	0.04	0.031	0.124	0.130	4.00
0.079	..	0.035	...	1.18	0.08	..	0.043	...	0.010	0.02	0.04	0.028	0.124	0.174	4.94
0.091	0.51	0.043	0.096	1.15	0.06	0.03	0.056	0.104	0.014	0.02	0.03	0.042	0.120	0.146	4.07
0.100	..	0.042	...	1.02	0.06	..	0.045	...	0.015	0.02	0.03	0.038	0.148	0.125	3.32
0.110	..	0.044	...	1.23	0.08	..	0.058	...	0.012	0.03	0.04	0.040	0.126	0.144	3.86

[a] The data given here were taken at random from the daily laboratory records of The A. M. Byers Co. covering a period of about six months at the mill at Warren, Ohio, by Prof. O. A. Knight.

[b] All figures are in percentages.

[c] Method described by Westcott, Eckert and Einert, *Ind. Eng. Chem.*, **19**, 1285 (1927).

iron made by hand-puddling, was a matter for more immediate consideration. This was made the main purpose of the study and this report summarizes the results obtained in a comparison of the properties of the two types of material. Both materials are referred to herein as "wrought iron." It is believed that the question of the inclusion of the new product under the term "wrought iron" is a matter that will automatically settle itself one way or the other in accordance with the degree of similarity of the two types of materials.

Table 2—Results of Chemical Analysis of Shotting Slag[a]

Before Shotting[b]				After Shotting[b]					
SiO_2	Fe	FeO	Fe_2O_3	SiO_2	Mn	P	Fe	FeO	Fe_2O_3
8.04	66.46	78.93	7.36	7.78	0.96	0.197	66.36	77.98	8.38
8.56	65.15	71.69	13.44	8.90	0.92	0.200	64.94	74.55	9.97
7.80	...	...	...	9.32	0.90	0.235	65.07	72.03	12.96
10.92	65.66	71.31	14.60	11.08	0.92	0.352	64.07	75.68	7.46
8.56	65.06	70.49	14.64	10.58	0.88	0.336	62.85	71.78	10.05
10.28	66.84	70.32	17.37	12.88	1.16	0.440	63.21	73.10	9.11
10.00	64.09	70.32	13.46	10.54	0.96	0.384	63.90	73.73	9.38
10.26	62.51	70.00	11.55	10.36	1.05	0.420	62.12	72.79	7.89
9.30	63.93	65.93	17.96	10.42	1.03	0.364	63.20	70.13	12.40
10.12	64.60	69.31	15.30	10.34	1.13	0.424	63.90	72.40	10.87
9.00	65.40	65.84	20.31	10.48	1.10	0.440	64.10	69.83	14.01
9.74	...	...	...	9.98	..	...	...	...	...
10.16	66.80	72.92	14.44	10.86	1.03	0.380	65.30	74.43	10.73
10.10	65.96	63.69	23.38	11.78	1.07	0.392	63.69	69.26	14.04

[a] The data given here were obtained in the same manner as those in Table 1.
[b] All results are in percentages.

Materials and Methods

Iron made by the Aston process is being used commercially only in the form of pipe, and this report deals only with this class of material.[10] In addition to the tests of the finished pipe, 1-inch butt-welded pipe being used throughout, similar tests were made on the pipe skelp, and on the muck bar, or "first rolling," that is, the product which is sheared into short lengths piled together, reheated and rolled into the form of skelp. Observations were also made upon the ball before it had been subjected to any working whatsoever. In all cases the tests were carried out on both hand-puddled iron and on the new product. Tests were also made on a composite iron in the form of pipe and skelp, made by using 50 per cent of each of the two irons in the form of sheared muck bar in forming the "pile," the hand-puddled iron forming the surface layers of the "sandwich," which was heated and rolled into the form of skelp. All samples used were taken under the supervision of the authors and represent "run-of-mill" material.

Four different strips of muck bar and of skelp were chosen at random, as they were rolled, and pieces representative of the "front," "middle" and "back" of the strip as rolled were cut out, the aim being to show the degree of uniformity of the material. The pipe samples were 10-ft. lengths of commercial black pipe of the three kinds; hand-puddled iron, new-process and the "composite iron" formed of equal parts of the other two. Three samples of each kind were used, the selection being made at random.

An identification mark was stamped on each sample at the mill so as to show (a) the nature of the iron (HP, hand-puddled iron; A, iron made by the Aston process; AHP, the composite iron); (b) the position of the sample in the strip, skelp or muck bar as rolled (F, front; M, middle; B, back); and (c) the number of the sample strip or pipe (1, 2, 3, 4). Thus, for example, "HPF1," as relating to skelp, indicates the piece cut from the front end of the hand-puddled skelp strip No. 1. These designations are used in summarizing the test results in this report.

Slag—Observations were made upon slag in rather large masses as well as upon slag which was obtained as "drippings" from the ball and also slag residues recovered from the finished pipe by solution methods.

Methods—In addition to the test methods which are commonly found in specifications for wrought iron pipe, a number of other tests were used, which, it was hoped, might reveal significant differences in the materials if they existed. Chemical analyses were made of both iron and slag. The physical testing methods used included density determinations as well as the usual tension, torsion and flattening tests. The structural examination of the materials, from both the microscopic and the macroscopic aspect, constituted an important part of the study. Laboratory corrosion tests were carried out on the finished pipe by various accelerated methods in both tap water and sea salt solutions, together with some determinations of the relative electrolytic solution potentials of the two types of iron. Mill observations were also made on the behavior of the irons during welding, galvanizing and machining.

Results

Composition—The samples for chemical analysis were short lengths from each end of three 10-ft. lengths of the new-process iron pipe, from each end of a similar length of hand-puddled iron pipe, and from a similar length of pipe made of the composite iron. It is apparent from the results (Table 3) that there is no marked difference in composition between iron made by hand-puddling and that made by the new process. The carbon and phosphorus contents were consistently lower in the new iron than in the hand-puddled product, but the sulphur content was slightly higher.

Table 3—Results of Chemical Analysis of the Three Types of Pipe Used[a]
(A = new process iron; HP = hand-puddled; AHP = composite iron x and y indicate the two ends of the pipe; 1, 2 or 3 indicate the number of the pipe sample)

Pipe Material	Determination, Percent							
	C	Mn	P(Total)	S	Si	Slag[b]	P(Slag)	Cu
A_{1x}	0.02	0.03	0.100	0.031	0.11	2.6	0.055	0.02
A_{1y}	..	..	0.100	...	...	2.7	...	..
A_{2x}	0.01	0.03	0.105	0.031	0.12	...	0.060	..
A_{2y}	..	..	0.100	...	...	...	...	..
A_{3x}	0.01	0.03	0.100	0.034	0.12	2.5	0.055	..
A_{3y}	..	..	0.100	...	...	...	...	..
HP_{1x}	0.03	0.04	0.150	0.019	0.22	3.0	0.075	..
HP_{1y}	..	..	0.145	...	...	...	...	..
AHP_{2x}	0.01	0.03	0.135	0.022	0.16	3.0	0.070	..
AHP_{2y}	..	..	0.135	...	...	...	...	..

[a] Analysis by H. A. Bright, Associate Chemist, Bureau of Standards.
[b] Iodine method—see American Society for Testing Materials, *Proceedings*, **25**, Pt. 1, 79 (1925).

The composition of the slag used in the new process agreed well with the average composition shown by the mill laboratory records. The difference in composition of the two types of slags (as determined on comparable samples) was slight and is not believed to indicate any important difference. Too much significance should not be attached to the apparent difference in composition (Table 4) of the slags determined on the residue obtained by dissolving the iron as compared with the slag in lump form. The $FeO:Fe_2O_3$ ratio of slag recovered as a residue may be altered as a result of the chemical method used.

Table 4—Chemical Composition of Slag

Material	Determination, Percent						
	FeO	Fe_2O_3	SiO_2	P_2O_5	MnO	CaO	Al_2O_3
Slag, Aston process (lump)	71.0	10.3	12.0	1.2	...	...	...
Same (recovered from the pipe)[a]	57.0	25.0	9.0	2.0	1.4	0.4	1.2
Slag, hand-puddling process (lump)	66.2	7.2	14.8	3.1	...	...	...
Same (recovered from the pipe)[a]	63.0	12.0	14.0	3.0	1.8	less than 1.0	.5

[a] The slag was separated from the pipe by the iodine method.

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[10] In the forthcoming Bureau of Standards publication, data on 1-inch rounds made especially for the investigation are also given.

Table 5—Density of Wrought Iron in Various Stages of Working[a]

(A = iron made by Aston process; HP = hand-puddled iron; AHP = composite iron containing 50 percent of each, A and HP; F, M and B = front, middle and back, respectively, x and y indicate the two ends of the pipe length)

Material			Density, G./Cm.³ 25° C.
Process	Rolled Product	Sample	
Aston	Muck bar	AF 1	7.63
		AM 1	7.65
		AB 1	7.58
	Muck bar	AF 4	7.61
		AM 4	7.57
		AB 4	7.65
		Average	7.615
Hand-puddled	Muck bar	HPF 1	7.53
		HPM 1	7.55
		HPB 1	7.60
	Muck bar	HPF 2	7.61
		HPM 2	7.62
		HPB 2	7.64
		Average	7.59
Aston	Skelp	AF 3	7.67
		AM 3	7.66
		AB 3	7.66
	Skelp	AF 4	7.68
		AM 4	7.67
		AB 4	7.68
		Average	7.67
Hand-puddled	Skelp	HPF 1	7.64
		HPM 1	7.65
		HPB 1	7.67
	Skelp	HPF 4	7.64
		HPM 4	7.63
		HPB 4	7.66
		Average	7.65
Composite	Skelp	AHPF 1	7.61
		AHPM 1	7.64
		AHPB 1	7.64
	Skelp	AHPF 4	7.64
		AHPM 4	7.63
		AHPB 4	7.64
		Average	7.63
Aston	Pipe	A 1 x	7.68
		A 1 y	7.66
	Pipe	A 2 x	7.66
		A 2 y	7.65
	Pipe	A 3 x	7.61
		A 3 y	7.64
		Average	7.65
Hand-puddled	Pipe	HP 1 x	7.62
		HP 1 y	7.62
	Pipe	HP 2 x	7.63
		HP 2 y	7.61
	Pipe	HP 3 x	7.61
		HP 3 y	7.62
		Average	7.62
Composite	Pipe	AHP 1 x	7.61
		AHP 1 y	7.62
	Pipe	AHP 2 x	7.61
		AHP 2 y	7.61
	Pipe	AHP 4 x	7.62
		AHP 4 y	7.63
		Average	7.62

[a] Density measurements by E. L. Peffer, Physicist, Bureau of Standards.

Density—The density of the three irons in various stages of working was determined (Table 5). On account of porosity, the results should not be considered as indicating in all cases the *true* density. They agree well, however, with other published results for the density of wrought iron and are believed to give reliable indications as to the relative densities of the three materials and of the variations in density in any one product. It will be noted that the average density of the new-process iron was consistently slightly higher in all of the products than that of the other two irons.

Mechanical Properties—The behavior of the three irons, in the form of muck bar, skelp and pipe, was determined under tension. Torsion tests and flattening tests were also made of the finished pipe.

Tensile Properties—The tensile properties of the iron, as muck bar ($^1/_2$ inch thick), were determined on 20-inch specimens with a reduced section $1^1/_2$ inches wide. The skelp specimens were of the same size except in thickness which was that of the skelp strip as rolled. This was approximately 0.133 inch, including the surface scale (0.03 inch), which flaked off during the test. The Ewing extensometer was used with a number of specimens in order to obtain the necessary data for the stress-strain curves (Figures 3 and 4).

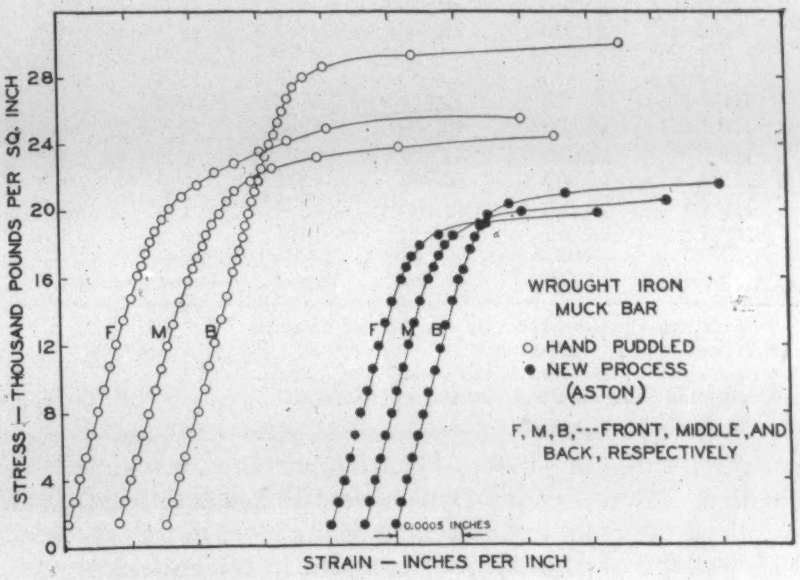

Figure 3—Stress-Strain Curves of Wrought Iron in the Muck Bar Condition Tested in Tension

The tensile properties of the two irons in the muck bar state are summarized in Table 6 and of the skelp in Table 7. Here and elsewhere, the values have been "rounded off" to the nearest 50 pounds.

Tension tests of full-size specimens as well as on strips machined from the pipe were made. An 18-inch specimen was taken from each end of 3 lengths of pipe. Snugly fitting plugs of mild steel were inserted in the ends of the pipe specimens to prevent them from collapsing in the jaws of the testing machine. The results of these tests are given in Table 8.

Many specifications for pipe permit the tensile properties to be determined on strips cut from the pipe instead of on the full-size pipe specimens. Although it is usually intended that the strip method shall apply only for pipe of large diameter, it is sometimes used for pipe of small diameter. It appeared of interest, therefore, to determine the tensile properties of

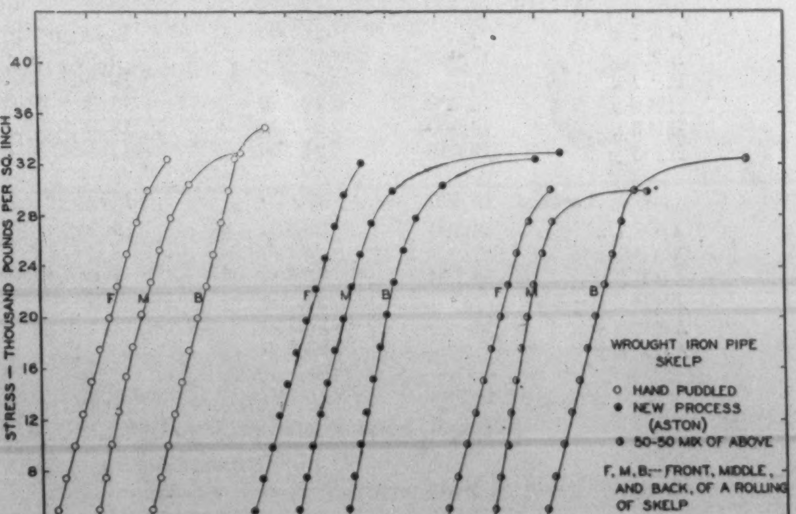

Figure 4—Stress-Strain Curves of Wrought Iron in the Form of Pipe Skelp Tested in Tension

Table 6—Tensile Properties of Wrought Iron in the Muck Bar State

(A = iron made by Aston process; HP = hand-puddled iron; F, M and B = front, middle and back of the muck bar strip as rolled)

Material	Tensile Properties				
	Yield Point[a]	Ultimate Tensile Strength	Elongation 2-inch	Elongation 8-inch	Reduction of Area
	Lbs./In.²	Lbs./In.²	Percent	Percent	Percent
AF 4	21,300	32,800	12.5	6.5	12.5
AF 4	20,800	43,300	34.0	21.5	20.0
AF 4	20,000	38,500	18.5	11.5	15.5
AM 4	20,850	38,000	17.5	10.5	11.0
AM 4	20,650	41,350	28.5	18.5	19.5
AM 4	20,000	31,450	[b]	[b]	7.0
AB 4	21,800	39,900	25.0	12.5	18.0
AB 4	21,200	42,250	27.5	20.0	19.5
AB 4	21,250	43,500	27.5	22.5	26.5
Average	20,870	39,000	23.9	15.4	16.4
HPF 1	[c]	13,600 [c]	...	...	...
HPF 1	25,500	40,350	17.5	9.5	10.5
HPM 1	24,300	34,000	[d]	5.5	5.5
HPM 1	27,000	40,550	12.5	6.5	9.0
HPB 1	29,400	42,400	13.5	7.0	10.0
HPB 1	28,000	49,300	18.5	13.8	18.0
Average	26,840	41,320	15.5	8.4	10.6

[a] From stress graph drawn by the Amsler machine.
[b] Broke outside of gage marks.
[c] Broke within the jaws of the machine at a weak spot.
[d] Specimen too rough to show the gage marks.

the three types of pipe on longitudinal strips machined from the pipe. The specimens, which were 18 inches in length, were machined, without any flattening of the pipe, so that the edges were parallel (not radial). The width in the shoulders was 2 inches and in the central portion, over a length of 10 inches, the width was 1 inch. The specimens were tested in an Amsler machine, special grips being used so as to maintain the original curvature throughout the test. The results are summarized in Table 9. It will be noted, by comparing these results with

Table 8—Tensile Properties of 1-Inch Wrought Iron Pipe as Determined on Full-Size Specimens

(A = iron made by Aston process; HP = hand-puddled iron; AHP = composite iron containing equal amounts of A and HP; x and y indicate the two ends of the pipe length from which specimens were cut)

Designation of Material	Tensile Properties [a]		
	Yield Point	Breaking Load	Elongation (8-inch)
	Lbs.	Lbs.	Percent
A 1 x	17,050	25,100	17.0
A 1 y	17,200	24,600	18.0
A 2 x	17,400	24,850	13.0
A 2 y	17,700	25,000	16.0
A 3 x		24,150	11.5
A 3 y	17,400	24,550	13.0
Average	17,350	24,700	14.7
HP 1 x	....	26,900	12.0
HP 1 y	19,000	25,700	8.0
HP 2 x	....	27,300	13.0
HP 2 y	18,700	26,850	13.0
HP 3 x	19,900	27,550	13.0
HP 3 y	19,650	27,700	12.5
Average	19,300	27,000	11.9
AHP 1 x	19,000	25,650	9.5
AHP 1 y	....	24,550	8.5
AHP 2 x	18,750	25,400	9.0
AHP 2 y	....	25,700	8.5
AHP 3 x	18,300	25,750	10.5
AHP 3 y	....	25,000	[b]
Average	18,700	25,350	9.2

Average Tensile Properties, Lbs./In.²

	Yield point	Ultimate tensile strength
A	33,150	47,250
HP	36,900	51,600
AHP	35,700	48,450

[a] A Riehlé testing machine, 100,000 lbs. capacity, was used; yield point was determined by drop of beam.
[b] Broke outside of gage marks.

Table 7—Tensile Properties of Wrought Iron in the Form of Pipe Skelp

(A = iron made by Aston process; HP = hand-puddled iron, AHP = composite iron, equal parts of A and HP; F, M and B = front, middle and back of the strip of skelp as rolled)

Material	Tensile Properties				
	Yield Point [a]	Ultimate Tensile Strength	Elongation 2-inch	Elongation 8-inch	Reduction of Area
	Lbs./In.²	Lbs./In.²	Percent	Percent	Percent
AF 1	29,550	44,100	26.5	21.0	24.1
AF 1	33,100	47,200	30.0	22.5	23.7
AM 1	30,550	44,950	22.3	18.0	20.2
AM 1	31,000	48,000	27.5	17.5	22.5
AB 1	31,800	47,200	33.0	24.5	25.2
AB 1	30,550	45,800	28.0	22.5	21.6
AF 2	32,000	44,600	21.0	17.0	21.6
AF 2	28,800	44,400	20.0	15.0	16.6
AM 2	27,100	41,600	17.5	12.0	17.2
AM 2	29,700	44,550	[b]	[b]	[b]
AB 2	30,450	42,400	16.0	11.5	15.2
AB 2	32,500	45,000	20.0	16.0	19.0
AF 3	29,850	44,500	19.0	16.5	16.4
AF 3	28,750	43,000	16.0	12.0	17.0
AM 3	28,600	44,200	20.0	14.0	16.7
AM 3	26,500	42,000	15.0	12.3	15.0
AB 3	31,900	45,000	20.0	11.5	19.5
AB 3	30,450	42,150	19.0	13.2	17.7
AF 4	29,500	44,650	32.5	20.5	24.0
AF 4	32,650	46,900	20.0	12.5	17.8
AM 4	31,500	48,200	17.5	15.0	22.0
AM 4	28,300	44,550	21.0	16.0	18.5
AB 4	32,000	45,500	25.0	21.0	23.5
AB 4	32,500	48,200	22.5	14.5	20.3
Average	30,400	44,940	22.8	16.3	19.7
HPF 1	32,500	46,000	16.0	11.0	18.0
HPF 1	34,000	45,150	13.0	9.5	13.7
HPM 1	31,300	46,700	19.0	13.0	16.6
HPM 1	32,000	47,250	17.0	13.5	17.0
HPB 1	33,600	47,250	17.5	12.5	16.0
HPB 1	36,100	46,750	17.0	12.0	17.6
HPF 2	32,350	46,550	20.0	15.0	18.1
HPF 2	34,000	44,350	12.0	9.0	14.7
HPM 2	31,500	40,500	10.0	6.2	11.5
HPM 2	32,350	42,800	[c]	[c]	9.9
HPB 2	36,500	46,250	15.0	10.0	12.0
HPB 2	36,450	47,800	17.5	14.5	15.2
HPF 3	33,000	42,000	11.5	7.5	11.5
HPF 3	34,350	45,950	18.0	13.0	17.1
HPM 3	32,050	42,400	[c]	[c]	..
HPM 3	32,000	45,550	13.5	10.2	15.5
HPB 3	33,850	43,450	12.5	9.0	9.5
HPB 3	34,000	43,000	14.0	8.0	14.5
HPF 4	34,500	43,500	11.0	5.5	10.5
HPF 4	34,150	42,300	11.0	8.0	15.5
HPM 4	34,850	45,450	10.0	6.0	9.1
HPM 4	33,000	41,100	7.5	4.5	7.1
HPB 4	33,850	45,000	12.5	9.5	13.5
HPB 4	36,300	46,450	12.0	6.2	8.1
Average	33,690	44,730	14.0	9.8	13.5
AHPF 1	32,150	41,100	8.5	6.0	10.5
AHPF 1	31,750	42,500	12.0	8.0	13.0
AHPM 1	31,500	40,500	[c]	[c]	13.0
AHPM 1	31,950	43,100	12.5	9.0	12.5
AHPB 1	32,850	42,800	12.5	9.0	11.5
AHPB 1	31,750	40,000	10.5	6.5	9.5
AHPF 2	31,000	38,000	9.0	5.5	10.0
AHPF 2 [d]	30,300	31,300	6.5	2.0	9.5
AHPM 2	30,050	39,400	11.0	7.0	13.3
AHPM 2	28,850	36,050	9.0	4.5	11.5
AHPB 2	34,150	43,550	18.5	14.0	16.3
AHPB 2	31,250	40,750	12.0	7.5	13.5
AHPF 3	33,600	44,150	[b]	[b]	[b]
AHPF 3	32,800	44,600	15.0	11.0	14.5
AHPM 3	30,500	43,000	13.5	10.5	14.0
AHPM 3	31,600	43,050	12.0	8.0	14.0
AHPB 3	31,500	43,000	13.0	9.5	14.5
AHPB 3	32,400	46,150	18.0	14.0	15.3
AHPF 4	31,250	42,000	11.0	7.5	10.0
AHPF 4	33,650	41,700	8.5	4.5	9.0
AHPM 4	29,500	37,500	6.0	4.5	10.0
AHPM 4	34,250	44,250	9.0	5.0	9.5
AHPB 4	33,400	42,700	[c]	[c]	10.5
AHPB 4	32,000	44,350	15.0	9.0	14.5
Average	31,830	41,480	12.6	7.7	12.6

[a] From stress graph drawn by Amsler machine.
[b] Broke in fillet.
[c] Broke outside of gage points.
[d] Rough defective specimen.

those in Table 8, that the most marked effect produced by using specimens of this form was the lowering of the elongation.

Table 9—Tensile Properties of 1-Inch Wrought Iron Pipe Determined on Longitudinal Strips Machined from the Pipe

(A = iron made by Aston process; HP = hand-puddled iron; AHP = composite iron containing equal parts of A and HP)

Material	Tensile Properties		
	Yield Point	Ultimate Tensile Strength	Elongation (8-inch)
	Lbs./In.^{2}	Lbs./In.^{2}	Percent
A	36,300	49,200	9.0
	33,400	47,350	8.0
	36,650	51,750	12.0
	33,700	48,250	9.6
	35,700	50,600	11.5
	35,150	49,500	10.0
Average	35,150	49,440	10.0
HP	37,500	52,250	8.8
	35,900	51,150	9.8
	38,500	52,050	7.0
	45,750	52,800	7.5
	39,850	56,100	13.1
	40,750	55,100	9.9
Average	39,700	53,240	8.9
AHP	36,100	50,300	8.0
	36,150	49,900	5.7
	38,100	51,850	7.0
	34,100	48,750	9.5
	38,950	49,900	5.0
	37,400	51,350	6.8
Average	36,800	50,340	7.0

Torsional Properties—Torsion tests were made on four specimens of each of the three kinds of pipe. The specimens for the tests, which were carried out in a Riehlé torsion testing machine of 60,000 lbs. capacity, were 44 inches in length and the ends were plugged as in the tension tests of pipe. The length between grips was 38 inches. The results obtained are summarized in Table 10 and the appearance of the pipe after testing is shown in Figure 5.

Flattening Tests—Six 6-inch specimens, of each of the three kinds of wrought iron pipe, were used in the flattening tests (Table 11). The load was applied perpendicularly along the entire length of the specimen and at 90° to the weld.

Corrosion Resistance—Laboratory corrosion tests.

The relative corrosion resistance of the three wrought iron pipes was studied by laboratory tests carried out in tap water and in a 3½ percent (by weight) sea-salt solution. The results of such tests, of course, may not be indicative of the behavior of the materials in service. However, under service conditions approximating in most respects the essential conditions of the tests, the service behavior of materials would be expected to follow the indications of the test results. Short pieces of the three kinds of pipe, 1¼ to 1¾ inches, were used. The sawed ends of samples were ground smooth on an emery wheel and the samples were cleaned free from grease by hot soap suds, rinsed in hot water, dried and weighed. No attempt was made to pickle the samples to remove adhering scale as it was desired to test the materials in a condition approaching as nearly as possible the commercial condition.

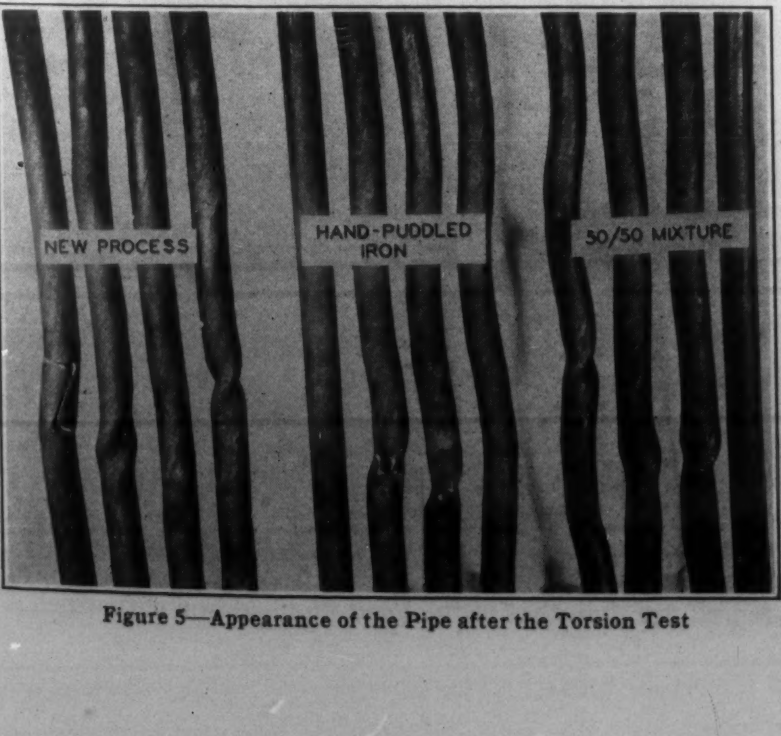

Figure 5—Appearance of the Pipe after the Torsion Test

Table 10—Torsional Properties of 1-Inch Wrought Iron Pipe

AHP 3^2(A = iron made by Aston process; HP = hand-puddled iron, AHP = composite iron containing equal parts A and HP)

Material	Torsional Properties		Twist	
	Yield Point,[a]	Maximum Moment	Total	No. of 360 Degree Twists
	Lbs.	Lbs.	Degrees	
A 1	6,000	9,850	1260	3.5
A 2	6,000	10,700	1465	4.07
A 3	5,900	10,300	1340	3.72
A 4	6,000	10,750	1380	3.83
Average	5,975	10,395	1361	3.78
HP 1	6,550	11,250	755	2.09
HP 2[b]	7,000	9,600	380	1.05
HP 3	6,800	11,650	1170	3.25
HP 4	6,850	11,450	1180	3.27
Average	6,800	10,985	871	2.42
AHP 1	5,000	10,450	1260	3.50
AHP 2	6,000	11,100	1450	4.03
AHP 3[b]	5,600	9,850	810	2.25
AHP 4	5,650	10,750	1500	4.16
Average	5,560	10,540	1255	3.48

[a] By drop of beam.
[b] The weld parted at the load end during the test.

Table 11—Results of Flattening Tests of 1-Inch Wrought Iron Pipe

(A = iron made by Aston process; HP = hand-puddled iron; AHP = composite iron containing equal parts of A and HP)

Material	Maximum Load	Remarks
	Lbs.	
A 1	9,150	All fractures were fibrous, no defective welds revealed
A 1	9,150	
A 2	9,950	
A 2	9,000	
A 3	8,200	
A 3	9,100	Not across the weld
Average	8,925	
HP 1	9,900	All fractures were fibrous, no defective welds revealed
HP 1	10,000	
HP 2	10,400	
HP 2	10,500	Not across the weld
HP 3	10,000	
HP 3	10,050	
Average	10,140	
AHP 1	9,600	All fractures were fibrous, no defective welds revealed
AHP 1	10,050	
AHP 2	9,500	
AHP 2	9,300	
AHP 4	9,975	
AHP 4	9,950	
Average	9,790	

The tests in both solutions consisted of the following: (*a*) immersion in the still liquid without any (intentional) aeration, (*b*) immersion in the liquid through which air was passed and (*c*) repeated immersion or "wet-and-dry" test. Twelve specimens from each of the three kinds of pipe (four specimens from three different pipe lengths) were tested in the two liquids by each of the three testing methods.

In carrying out the simple immersion tests, without aeration, eight samples, in two sets of four placed end to end and held in place by means of glass rods extending through the pipe, were immersed in the liquid to a depth of approximately 3 inches. Large glass battery jars were used as containers, and water was added from time to time to maintain the initial volume (4 liters) of the liquid. In carrying out the immersion tests, with aeration, the samples were placed end-to-end within a rubber tubing (inside tube of a bicycle tire), the whole being immersed in the liquid in a large container. Air was bubbled slowly through the inside of the assembled specimens during the day time (8 hours). The repeated immersion, or "wet-and-dry," tests were carried out by means of an apparatus controlled by a clock, so that the specimens, which were supported by cords and glass rods, were wet at 15-minute intervals with the liquids (tap water or sea-salt solution) by being dipped momentarily into the solution and then raised into the air. The specimens were immersed in the liquid approximately 1 minute at each immersion. The corrosion tests were allowed to continue for 3 months (92 days) except in the case of a few specimens which were examined at the end of two months. No attempt was made to remove the corrosion product during the period of corrosion. The tests were carried out during the three summer months at room temperature. At the end of the three-month period, they were cleaned free from the corrosion product, washed first in hot water and then in alcohol, dried and weighed. The loss of weight per unit of surface area was used as a basis of comparison.

No marked or important difference in the character of the corrosion product on the different kinds of iron was noted. The character of the corrosion product differed decidedly, however, according to the conditions under which the corrosive attack had occurred. A loose flocculent deposit which could be removed very readily was formed on the specimens after corrosion by simple immersion (unaerated) in both tap water and salt solution. The deposit which formed on the specimens corroded in the aerated solutions was much more adherent but was readily removed by means of a bristle brush. In the case of the wet-and-dry tests, however, the character of the scale formed was decidedly different from that in the other tests and was removed only with difficulty. On the specimens corroded in the sea-salt solution, the scale, though much more adherent than in the other cases, was coarse and was removed by vigorous brushing. The scale on the specimens corroded by repeated immersion in tap water, however, though thin, was smooth and very adherent. It was removed with a bristle brush with great difficulty even after the specimens had been allowed to remain in a 10 percent (by weight) solution of ammonium citrate for two days.

A summary of the average corrosion loss of the three kinds of pipe when corroded in different ways in tap water and in sea-salt solution is given in Table 12 and a graphical summary of the results of the corrosion tests in Figure 6. As shown by the data in Table 12, there appears to be a very slight difference in the corrosion rate of the hand-puddled and the new-process wrought iron in favor of the hand-puddled product.

Table 12—Average Corrosion Losses of Wrought Iron Pipe in Accelerated Laboratory Tests of Three Months' Duration

(A = iron made by the Aston process; HP = hand-puddled iron; AHP = composite iron containing equal amounts of A and HP)

Material	Corrosion Method					
	Simple Immersion		Immersion Aerated		"Wet-and-Dry"	
	Sea-salt Solution[a]	Tap Water	Sea-salt Solution[a]	Tap Water	Sea-salt Solution[a]	Tap Water
A	0.0063[b]	0.0074	0.031	0.0215	0.140	0.073
HP	0.0061	0.0072	0.029	0.0217	0.125	0.047
AHP	0.0059	0.0077	0.034	0.0207	0.168	0.057

[a] $3^1/_2$ percent solution, by weight.
[b] Grams/dm.^{2}/day.

Electrolytic Solution Potential—Coincident with the laboratory corrosion tests and before the results of these tests were known, a few simple tests were carried out to show the relative behavior of the two wrought irons (new process and hand-puddled) when in electrical contact with each other and immersed in a solution. Small pieces of the skelp strip, 3 by $^3/_4$ inch, were used as specimens. These were cleaned by pickling, after which they were heated in an oven to approximately 200° C. in order to drive off any hydrogen present. A copper wire was firmly attached to one end of the specimen and the junction of iron and copper as well as the wire itself coated with paraffin. A dilute solution of sodium sulphate (1 percent, by weight) was used as the electrolyte in which the two iron specimens were immersed, "face to face," slightly more than one inch apart. A small portable potentiometer was used to show the magnitude and direction of the e. m. f. which resulted when electrical contact was established between the two specimens.

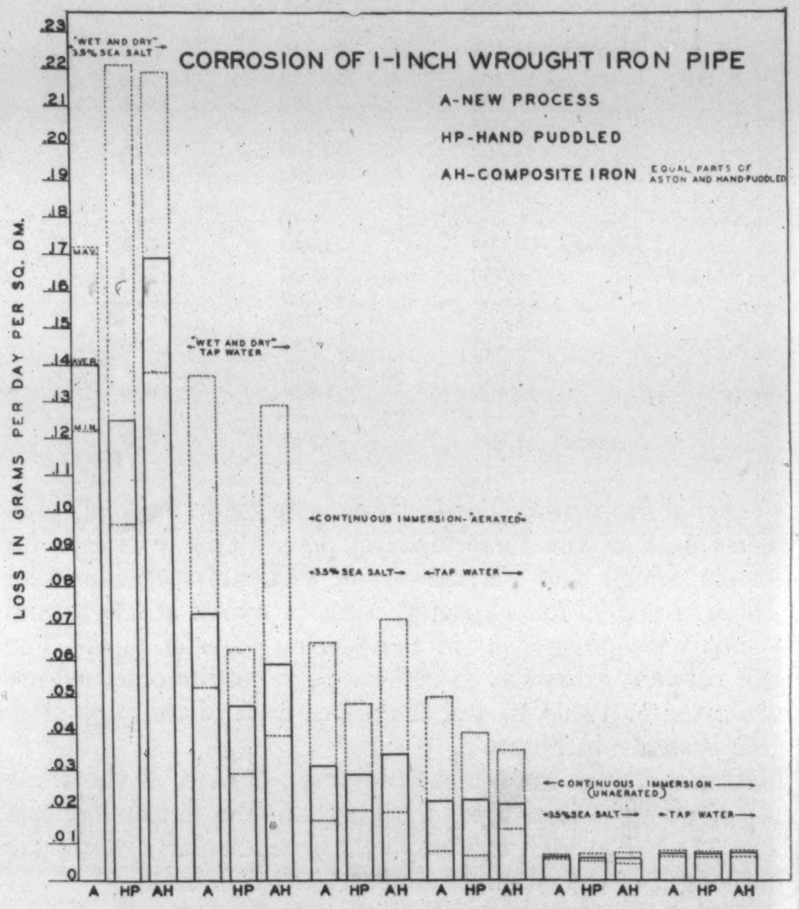

Figure 6—Summary of the Results of the Corrosion Tests

There was considerable variation in the e. m. f. observed for several different couples as well as for the same couple used on different days. This is not surprising in view of the simple method used. The e. m. f. varied from approximately 11 to 53 millivolts. The results were consistent, however, in one important respect. The hand-puddled iron was, in all cases, the cathode of the couple, that is, for the conditions used, the so-called "solution pressure" of the new-process iron was very slightly higher than that of the comparison material.

Structural Examination—The structural condition of wrought iron is one of its most characteristic features, and the comparison of the structure of the two types of iron was carried out in considerable detail.

Ball—A wrought iron ball taken from the hand-puddling furnace and a ball of the wrought iron made by the new process as it comes from the shotting cup do not differ greatly in appearance except in size. The microstructure of the two irons was examined on a considerable number of fragments in order to obtain a good idea of the average structure. Figure 7 is representative of the conditions found. After etching the hand-puddled ball, evidence of the presence of carbon was frequently found. The metal was quite "patchy" in this respect. The condition shown in the micrograph is not unusual. The structural condition of the new-process iron in the ball was much more uniform than that of the hand-puddled iron with which it was compared. The degree to which the continuity of the iron matrix was broken up during the shotting operation and the slag was mechanically incorporated with the iron is surprising. In addition to the coating of slag covering the globules of iron formed by the shotting operation, the interior of globules showed an intimate mixture of the slag often suggestive of a dendritic arrangement. No evidence of the presence of carbon was found upon etching this iron.

Muck Bar—The microstructure of the muck bar, as shown in Figure 8, was found to be in agreement with that of the ball. The hand-puddled iron showed occasional slag streaks which were considerably larger than any found in the comparison iron and streaks of metal with a rather high carbon content were not uncommon. No carbon streaks were found in the muck bar of the new-process wrought iron and the average distribution of the slag threads was considered to be somewhat more uniform. In the comparison of the two irons, the examination of transverse sections was used more than longitudinal sections since a transverse section is a much better index of the distribution of the slag streaks than is the other. Only a very few of the numerous micrographs which were taken can be reproduced here.

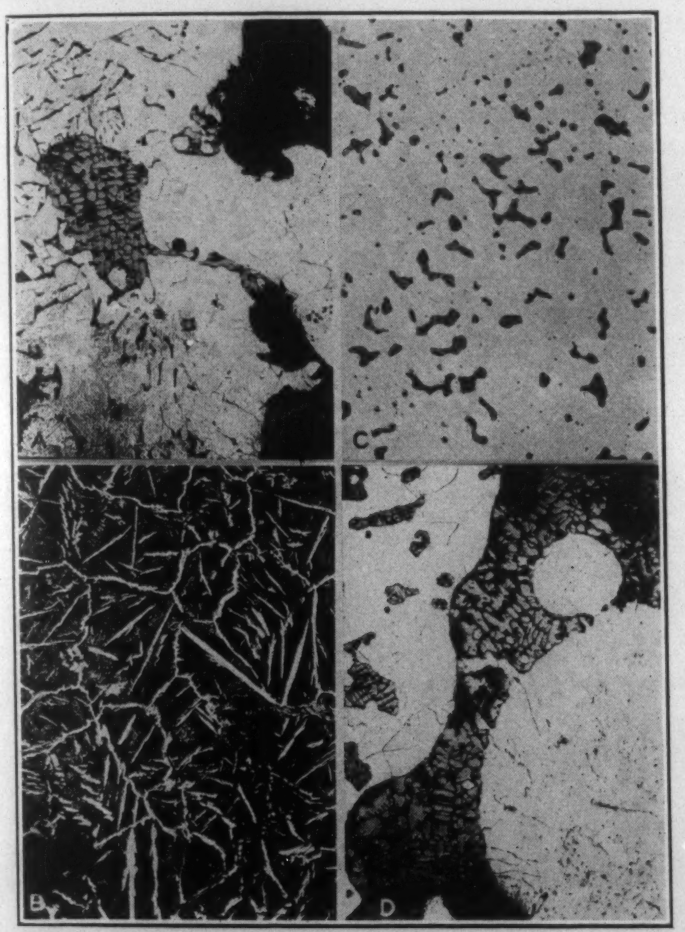

Figure 7—Microstructure of Wrought Iron in the "Ball" Stage, x 100 ($^{1}/_{2}$ Reduction). Etchant, Picric Acid
A, hand-puddled iron. This condition prevailed throughout much of the ball
B, a high-carbon area in the hand-puddled ball
C, iron made by the Aston process showing how the slag is thoroughly disseminated throughout the iron matrix (unetched)
D, another area showing larger masses of slag, etched

Skelp—The examination of samples of the skelp taken from the front, middle and back of the strip as rolled, showed no important differences in the structure corresponding to these three positions. The average distribution of the slag threads together with some of the largest slag threads found, as seen in transverse sections of each of the three kinds of skelp, is shown in Figure 9. The examination of this material after etching showed considerably more uniformity with respect to carbon distribution in the hand-puddled product than was found in the muck bar and ball stages of this material. This is a natural consequence of the heating which the "piles" formed from the sheared muck bar received prior to the rolling into skelp. The average carbon content of the streaks which were found was estimated from the microstructure to be 0.15 to 0.20 percent. A few of these streaks were found in the skelp rolled from the composite pile made of equal parts of the two types of iron.

Pipe—The structural condition of the iron after being worked into the form of pipe is depicted in Figures 10 and 11. There were no features found in any case which are not common in commercial wrought iron pipe. The relatively "cleaner" appearance of the pipe made from the new iron and particularly the absence of "carbon streaks" is noteworthy. No very marked differences in the slag distribution in any of the three irons were noted.

Slag—Wrought iron slag is essentially a ferrous silicate slag. According to Herty and Fitterer,[11] such slags containing silica in amounts less than 29 per cent contain two constituents, FeO and a silicate, fayalite ($2FeO.SiO_2$). The eutectic for this part of the system occurs with a silica content close to 21

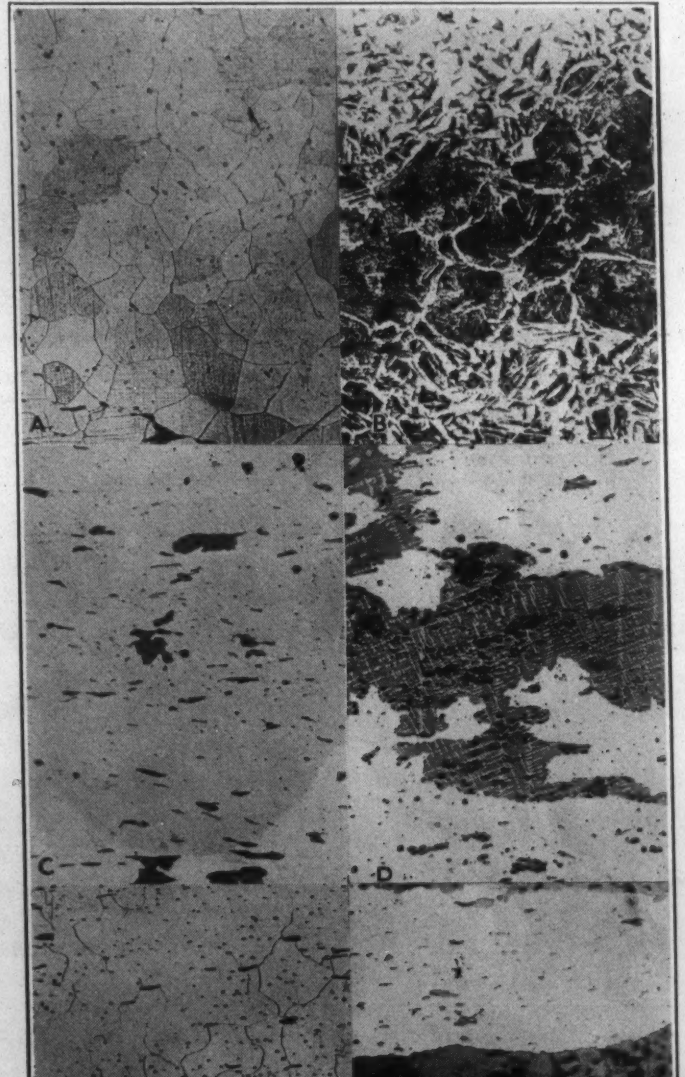

Figure 8—Microstructure of Wrought Iron in the Muck Bar Stage, x 100 ($^{1}/_{2}$ Reduction). Etchant, Alcoholic Picric Acid Solution
A, hand puddled iron, etched, transverse section showing no carbon and very little slag
B, same showing high-carbon streaks
C, hand-puddled iron, unetched, transverse section showing average slag condition
D, same, showing large slag masses
E, wrought iron made by the Aston process, etched transverse section showing average slag conditions. No evidence of combined carbon is shown
F, similar section, unetched, showing large slag streaks

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[11] C. H. Herty and G. R. Fitterer, "The Physical Chemistry of Steel Making: Deoxidation with Silicon and the Formation of Ferrous-Silicate Inclusions in Steel," Mining & Metallurgical Investigations, Carnegie Institute of Technology and Bureau of Mines, *Bull.* **36** (1928).

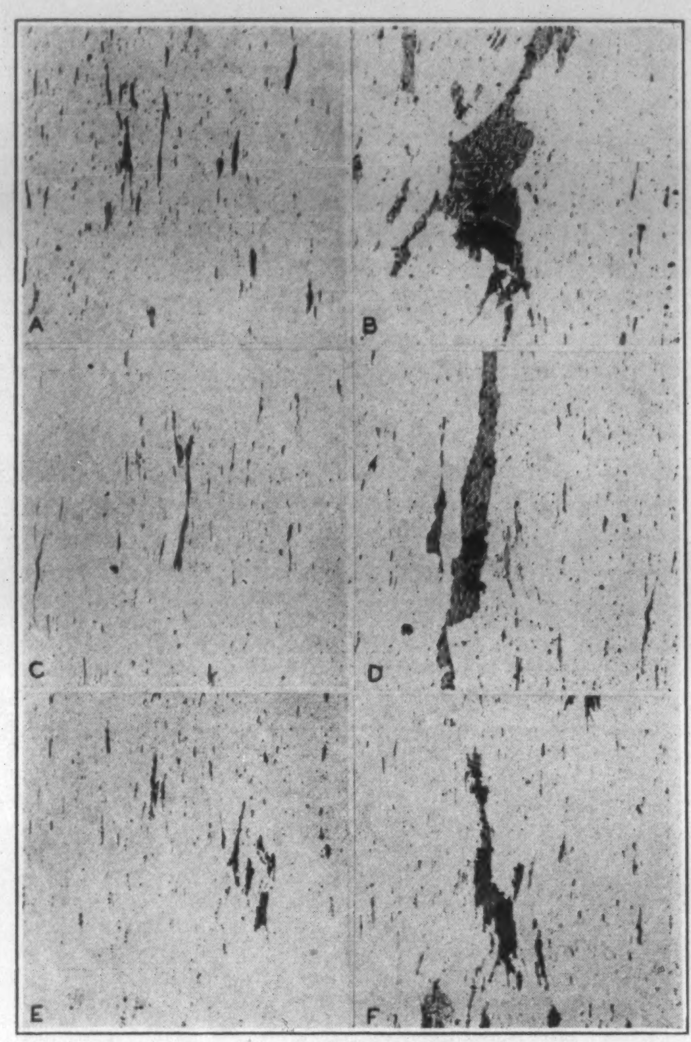

Figure 9—Microstructure of Wrought Iron in the Form of Pipe Skelp
The micrographs are of unetched transverse sections and represent the average condition of the slag (left) and some of the large slag threads (right)
A, B, hand-puddled iron
C, D, new process iron
E, F, composite iron

percent. Pure ferrous silicate slags containing less than 21 percent silica, therefore, consist of excess FeO embedded in a eutectic matrix of FeO and fayalite. This is the structural condition which obtains in wrought iron slags ordinarily. The eutectic is extremely fine and appears as a single constituent at the magnifications ordinarily used in studying the structure of wrought iron.

It will be noted (Figure 12) that the slags representative of hand-puddling and of the new process have the same structure and show no differences in structure which can be considered as significant of marked differences in properties. These samples, which were secured as "drippings" from the wrought iron "ball," were remelted in the laboratory in iron crucibles and allowed to cool slowly in the furnace so as to approach a condition of equilibrium. In practice, wrought iron slags always contain phosphorus in appreciable amounts as well as other substances in smaller amounts. Evidence of other structural constituents besides FeO and fayalite will nearly always be found in such slags.

Miscellaneous Tests and Observations—Observations on blistering.

It is well known that "blisters" are quite common on the inner surface of wrought iron pipe of the smaller sizes. In cutting up the pipe lengths used in this study which had been chosen at random without any inspection whatsoever, a few blistered areas were noted and in such cases that portion of the pipe was not used for test specimens. It is noteworthy that such blisters were confined almost entirely to the pipe made from the hand-puddled iron. Undoubtedly the formation of these blisters is associated with the occasional "carbon streaks" which occur in this type of iron and is to be attributed to the liberation of gas (CO) in the reaction between the combined carbon and the ferrous oxide of the slag. The fact that the

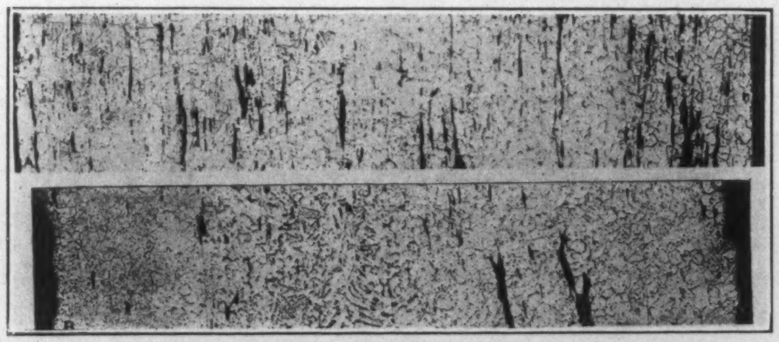

Figure 10—Microstructure of Hand-Puddled Wrought Iron Pipe, x 75 ($^1/_3$ Reduction)
Sections of the entire wall of two 1-inch pipes are shown; A, longitudinal section; B, transverse section; etchant, alcoholic picric acid solution
Note the pearlite in "B"

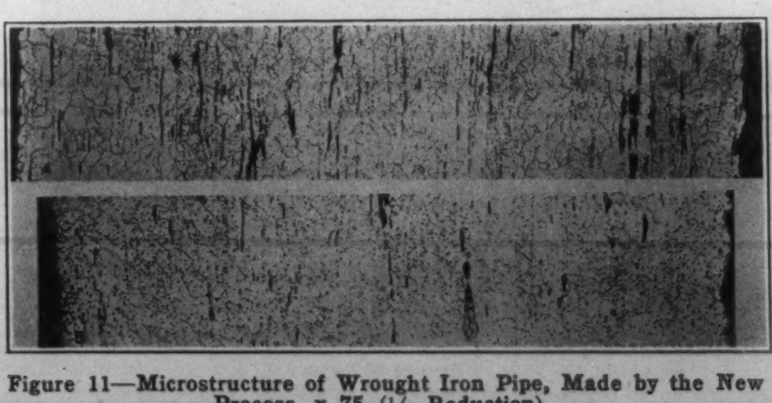

Figure 11—Microstructure of Wrought Iron Pipe, Made by the New Process, x 75 ($^1/_3$ Reduction)
Sections of the wall of two 1-inch pipes are shown; A, longitudinal section, B, transverse section; etchant, alcoholic picric acid solution

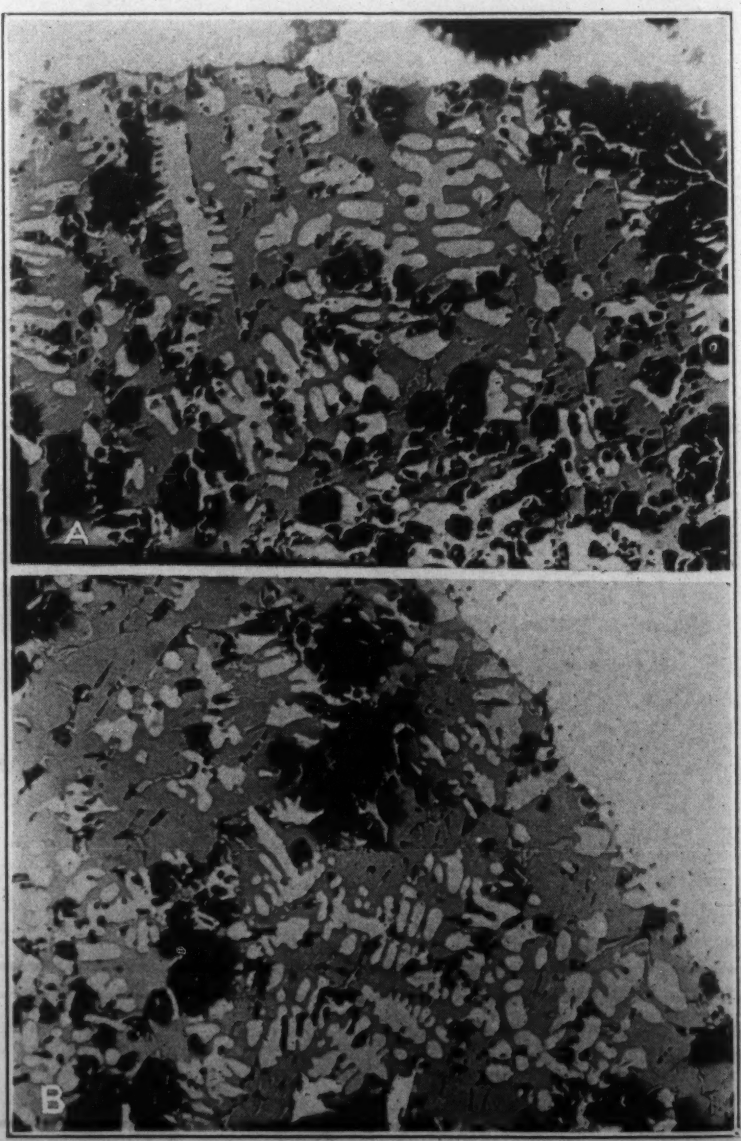

Figure 12—Microstructure of Wrought Iron Slag, x 100 ($^1/_4$ Reduction)
The slag, which was obtained as drippings from the ball, was remelted in iron crucibles and allowed to cool slowly in the furnace
A, slag used in the Aston process
B, slag from hand-puddled iron
The light-colored constituent is FeO, the gray matrix is fayalite, the black spots represent cavities formed during the grinding of the surface. The eutectic nature of the matrix cannot be seen at this magnification

iron made by the new process has a very low carbon content (rarely over 0.03 percent) in all stages of fabrication, from the ball to the finished type, will probably account for the relatively high degree of freedom of this type of pipe from this feature.

Mill Observations—"Weldability" and ease of machining rank high among the desirable characteristics of wrought iron. Observations on the relative weldability of the two types of iron as it was being made into pipe were made in the mill together with the usual flattening and hydrostatic tests which form part of the routine mill tests. The new-process iron behaved in all essential respects in these tests like the hand-puddled iron. Such visual observations as it was possible to make on the machining of the pipe in the mill indicated no difference on the behavior of the two irons during the threading of the ends of the pipe. Likewise the observations made on the behavior of the two during galvanizing, supplemented by flattening tests of the galvanized pipe, indicated that the "galvanizing properties" of the new iron are equal in all respects to those of the hand-puddled product.

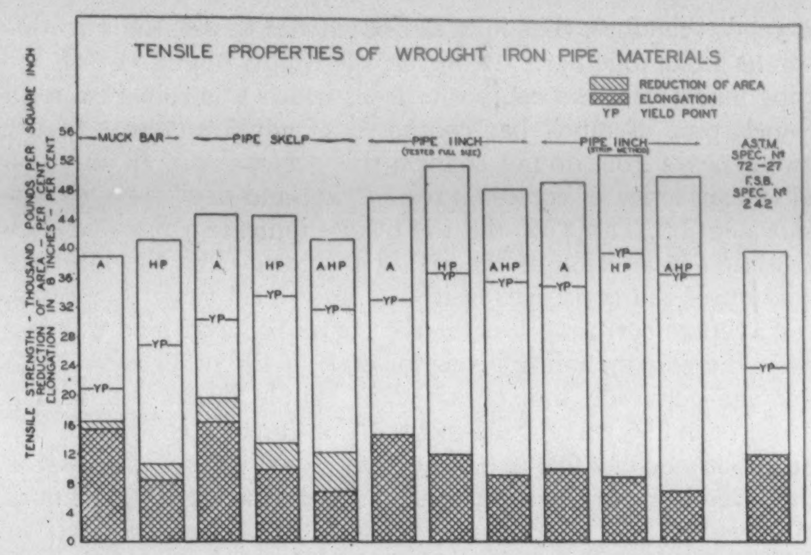

Figure 13—Comparison of the Tensile Properties of Wrought Iron Pipe with Specification Values

A, new-process iron, HP, hand-puddled iron, AHP, the composite iron containing equal parts of A and HP

Discussion

Wrought iron is conceded to be a malleable product formed from the refining of pig iron (or ore) by the almost complete elimination of the metalloids in the material and, in the wrought state, has a characteristic structure referred to as "fibrous," which is the result of the intimate mechanical mixture of some slag with the iron. Since wrought iron is a mixture of two unlike substances, the composition, as determined by ordinary chemical analysis, cannot readily be used as a basis of a definition as may be done in the case of steel. The "refining" of the raw material must necessarily be quite complete in order to obtain a malleable product. The metalloids initially present in the pig iron, if not entirely eliminated, are reduced to a very small percentage. Aside from the restriction concerning the maximum percentage of manganese permitted, for example, 0.10 per cent,[12] chemical composition is not usually specifically mentioned in specifications for wrought iron. In the results of the chemical analyses of the different irons summarized in Table 3, nothing will be found which could be used as a basis of adverse criticism of any of the irons. It will be noted that the carbon content of the new-process iron was consistently lower throughout all stages of fabrication than that of the comparison iron, and, as shown by the metallographic examination, this product showed no non-uniformity such as would result from "carbon streaks." It is not to be inferred, however, that non-uniformity by the presence of carbon streaks is *necessarily* a characteristic of all wrought iron made by the hand-puddling process.

On the basis of the density measurements, there is little to be said concerning possible differences in the two types of iron.

For purpose of comparison, the average tensile properties of the pipe materials have been summarized in Figure 13. The properties of the iron in the form of muck bar are, of course, of no "practical" concern. It may be of some interest, however, to note that iron made by the new process even in this rough form, showed considerably higher ductility, though with a somewhat lower tensile strength, than the hand-puddled iron did. The presence of combined carbon in the latter in sufficient amounts as to form easily recognized "carbon streaks" may be the reason for this. The working which the materials received in putting them into the form of skelp and pipe improved the tensile properties. It will be noted, however, that, in general, the hand-puddled iron after the additional rolling still showed somewhat higher tensile strength, accompanied by lower ductility, than did the comparison wrought iron.

By comparison with the tensile properties for wrought iron pipe of this size as required by specifications of the American Society for Testing Materials and the Federal Specifications Board,[13] it will be seen that both the hand-puddled wrought iron and the new-process wrought iron, when tested as full-size specimens, would meet the required tensile properties. However, when the tensile properties were determined on longitudinal strips machined from the pipe, as is permitted by current specifications, the average elongation was found to be lowered very considerably. This lowering of the elongation is to be attributed to the *form* of the test specimen and not to any inherent property of the iron. The specimen, in each case, represented the full wall thickness and the initial curvature was maintained through the test. On the basis of these tests, it would appear that in testing pipe of small diameter, the strip method, at least as carried out here, is not suitable and should not be depended upon.[14]

The torsional properties of wrought iron are not ordinarily taken into account in specifications for pipe. For rotary drill pipe, of course, the behavior of the pipe under torsion may be of considerable importance. The torsion tests, in the present study, however, afforded another convenient means for comparing the properties of the two irons, in the form of pipe, particularly the relative ductility and soundness of the welds. The results of the torsional tests confirmed those of the tension tests in showing that the hand-puddled iron used was a slightly stronger but less ductile material than the comparison wrought iron.

In carrying out the corrosion tests, no attention whatsoever was given to the controversial question as to the relative corrodibility of wrought iron and steel. The sole purpose of the tests was to show whether or not the corrosion behavior of the two types of iron, in the form of pipe, differed to any marked extent. A comparison of the results for the wrought iron made by the new process with those for the hand-puddled product may be taken to indicate a very slightly higher corrosion resistance for the latter. These indications seem to be in accord with the results of the tests carried out to show the relative electrolytic solution potential of the two. The results of these tests indicated that new-process iron, when in electrical contact with the hand-puddled iron, both being immersed in a solution, has a slightly higher solution pressure. It might be argued, therefore, that it would be unwise to use the two different kinds together. However, the results obtained with the pipe made from the composite iron, which was rolled from an 8-inch pipe of muck bar composed of equal amounts of the two types of iron, do not confirm this conclusion. In only one of the six series of corrosion tests ("wet-and-dry" tests in sea-salt solution, Table 12) did the results indicate a possible electrolytic acceleration of the attack resulting from the intimate contact of the two types of iron. In at least two other cases, the average corrosion loss for the composite-iron pipe was less than the corresponding losses for each of the other two. The average corrosion loss obtained in simple immersion in tap water or in $3^1/_2$ percent sea-salt solution (unaerated) was in the neighborhood of 0.006 to 0.007 g./dm.^{2}/day, whereas the loss for the same irons in the same solutions, when aerated for 8 hours of every 24, was approximately 4 to 5 times as great (0.021 to 0.034 g./dm.^{2}/day). In the wet-and-dry corrosion tests, the loss was much more pronounced (0.125 to 0.168 and 0.05 to 0.07 g./dm.^{2}/day in sea-salt solution and tap water, respectively). It may be concluded, therefore, that the effect, on the corrosion behavior of these materials, of the conditions under which the corrosive attack was brought about far overshadowed any possible effect caused by differences in the materials themselves.

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[12] Specifications A 84-27 and A 86-27, Amer. Soc. Test. Materials Standards, 1927.

[13] Standard Specifications A 72-27, Amer. Soc. Test. Materials Standards, 1927; also Federal Specifications Board, Specification 242, "Wrought Iron Pipe, Welded (Black and Galvanized)," 1925.

[14] Specification 242 of the Federal Specifications Board is now being amended in this respect, the question having been brought up for consideration by another manufacturer of wrought iron pipe. For the determination of the tensile properties of pipe 2 inches in diameter and less, the tension specimens consist of full-size pipe sections, the strip method being restricted to the pipe of larger diameter.

Of the different corrosion methods used, the immersion tests, without question, are more nearly representative of conditions for pipes in service than the wet-and-dry tests are. And of the two types of immersion tests, those carried out in tap water without excessive aeration probably represent service conditions for the large majority of pipe better than the other immersion tests. On the basis of the results obtained with the simple immersion tests in either of the liquids used, no distinction as to the relative merits of the various materials can be drawn. Likewise, the average corrosion losses obtained in the immersion tests in aerated liquids, especially those in tap water, do not differ sufficiently to warrant specific conclusions being drawn as to the relative corrosion resistance of three materials.

Concerning the similarity in structure of the two types of iron, little need be said. The micrographs clearly show that the product made by the new process has the structural features which are generally considered to be characteristic of wrought iron. Indeed, it is extremely doubtful whether any metal microscopist could distinguish with certainty a sample of the new wrought iron from iron made by the more familiar puddling process if the sample were submitted to him as an "unknown." The almost complete absence of carbon streaks from the structure of the iron made by the new process is a noteworthy feature and any possible distinction between the two irons from the standpoint of structure would undoubtedly have to be drawn on this basis.

The examination of the slag from the two different processes showed that both were essentially ferrous silicate slags containing an excess of iron oxide, although not absolutely identical in either chemical composition or structure. The slight differences, however, would not seem to be of importance from a practical standpoint so far as the properties and use of the finished product are concerned. In the observations made in the mill, especially on the welding, galvanizing and machining properties of the two types of iron in the form of pipe, nothing was seen to indicate any marked differences in the two irons in these respects.

Summary

1. A comparison was made of the properties and structure of wrought iron made by the hand-puddling process with those of wrought iron produced by a new process. The new process differs radically from the conventional hand-puddling process in that the pig iron after being melted in a cupola is refined in a Bessemer converter and then incorporated with the slag which is prepared in a separate furnace. The "shotting" operation by which the slag is intimately mixed with the iron consists in pouring the molten metal into a bath of the molten slag. The resulting "ball" after being squeezed into a bloom is rolled in the ordinary manner into the desired shape. The comparison tests were carried out upon commercial 1-inch butt-welded black pipe since, as yet, the commercial use of the new process is confined almost entirely to pipe. Three types of pipe were used, hand-puddled iron, new-process iron, and a "composite" iron composed of equal parts of the other two. Tests were also made upon the muck bar and skelp from which the pipe was rolled. The samples were chosen at random in the mill and each length was sampled so as to obtain samples representative of the front, middle and back, as rolled, of the strips selected. All of the succeeding tests were made on all of these samples.

2. The chemical composition of the iron made by the new process was found to agree closely with that of the hand-puddled iron. The carbon content was consistently lower in the new-process iron than in the comparison iron and more uniform in that "carbon streaks" were entirely absent in the structure as shown by metallographic examination. The sulphur content of the new-process iron was not quite so low as that of the hand-puddled product.

3. No marked differences in density were found in the irons. The new-process iron had a slightly higher density but the difference was so slight as not to have any practical significance.

4. No marked difference in mechanical properties was found in the two irons, in pipe form, as shown by tension, torsion and flattening tests. The iron made by the Aston process, on the whole, showed a slightly lower tensile strength accompanied by higher ductility. Pipe made from the new-process iron meets the requirements of current specifications for pipe of the American Society for Testing Materials and the Federal Specifications Board so far as could be determined by the testing methods employed in this study.

5. The accelerated laboratory corrosion tests indicated a very slight difference in the corrosion resistance in favor of the hand-puddled iron. The difference, however, was extremely slight as compared with the differences in corrosion behavior resulting from the different test methods used.

6. The structural features of the iron made by the Aston process are those which are generally conceded to be characteristic of wrought iron in general. The absence of "carbon streaks" in the new-process iron appears noteworthy. It is not to be concluded, however, that this feature is necessarily always present in hand-puddled iron. However, the hand-puddling process is not nearly so favorable for the complete elimination of carbon as is the new process. The occurrence of occasional relatively large slag threads in the hand-puddled iron was more frequent than in the comparison material according to the examination made.

7. Although not a primary object of this investigation, general observations made of the hand-puddling process and of the Aston process indicate a close parallelism in the important reactions entering into the manufacture of wrought iron in the two cases. The similarity of the products of the two processes confirm this indication.

8. In the observations made in the mill nothing was observed that would indicate that the behavior of the new-process wrought iron in welding, galvanizing and machining is inferior in any respect to the wrought iron with which it was compared.

Acknowledgments

In addition to the acknowledgments made throughout the text, the authors wish to express their indebtedness to C. E. Eggenschwiler, Junior Laboratory Assistant, for his help in a great many of the tests reported.

X-Ray Metallography in 1929*

By George L. Clark[1]

3. The Diffraction of X-Rays by Metals and Alloys

1. The Production of X-Rays. The general method of producing X-rays is now familiar to everyone conversant with modern scientific developments or, as a matter of fact, to everyone who has seen the physician or dentist use his apparatus for diagnosis. The X-ray tube is an arrangement whereby a stream of negatively charged electrons or cathode rays may be made to bombard a metallic target which constitutes the anode of a 2-electrode vacuum tube. The cathode stream may have several possible sources, but in all of the X-ray tubes now in practical use there are only two sources which serve to classify them: a hot wire filament cathode furnishing by thermal emissivity a supply of electrons independently in a vacuum too high to permit any high potential discharge through residual gas; and a cold metal cathode in a tube with sufficient residual gas so that the high potential discharge disrupts the gas molecules into positively changed ions and electrons, which, with those liberated from the cathode by impact of the positive ions, bombard the target and excite X-radiation.

The first type of tube is of the Coolidge or electron type and the second is the gas-type tube. The latter is, of course, historically the first since Roentgen discovered X-rays with such a tube in 1895. With the advent of the Coolidge-type tube with its self-rectifying power and its greater convenience, because of the independence of voltage and current through the tube and because of the fact that it could be purchased already evacuated and ready for use, the gas-type tube was very largely displaced. As the application of X-rays to the study of the fine structure of matter has increased, however, the gas-type tubes have again come into wide usage in research laboratories, particularly when softer rays (greater wave-lengths) are required as in the analysis of organic compounds.

One of the familiar varieties of gas-type tubes is the Hadding-Siegbahn. This is a rugged metal tube with porcelain insulator which may be taken apart easily and the targets of different metals interchanged. As shown in Fig. 9, the X-ray beam passes out through three very thin metallic windows very close to the target so that the minimum loss of intensity through absorption is suffered. It is true that the tube must be continually pumped and that it operates satisfactorily only at a gas pressure of 0.011 to 0.013 mm. With modern pumping equipment, however, this is not difficult. An oil pump is used as the first stage and a mercury diffusion pump as the second. The pressure is therefore reduced below that required for operation but by use of a needle valve or connection with the oil pump directly, enough air is re-admitted to give the proper conditions. Another familiar gas-type tube is the Shearer-Hilger (Fig. 10) which is all metal except for a glass tube which serves as the body of the tube while insulating the cathode from the target. In all these tubes the cathodes are of aluminum with concave surfaces for the purpose of focusing the cathode rays on the target. The proper radius of curvature may be calculated for a given distance between electrodes, or the proper distance to yield the most intense rays may be determined rapidly by trial. All of these tubes provide for water-cooling of the target and also for some cooling of the aluminum cathodes.

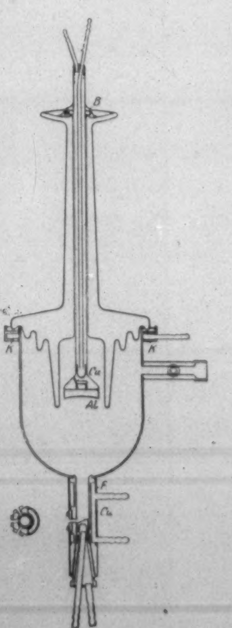

Figure 9—Hadding-Siegbahn Gas-Type X-ray Tube Used in Crystal Analysis

Coolidge-type tubes (Fig. 11) may also be designed for disassembling and for interchanging targets, though those commercially available in this country are permanently constructed with copper-glass seals and are pumped out at the factory. When the tube fails by development of gas, cracking, etc., it must be returned for repair or replacement. One such tube operating *continuously* at 20 milliamperes recently failed only after 5000 hours in the writer's laboratory. A recent modification by Davey, in which the electrodes are brought much closer together, has proved highly successful in increasing tube life, particularly in protecting the glass walls from wandering cathode rays.

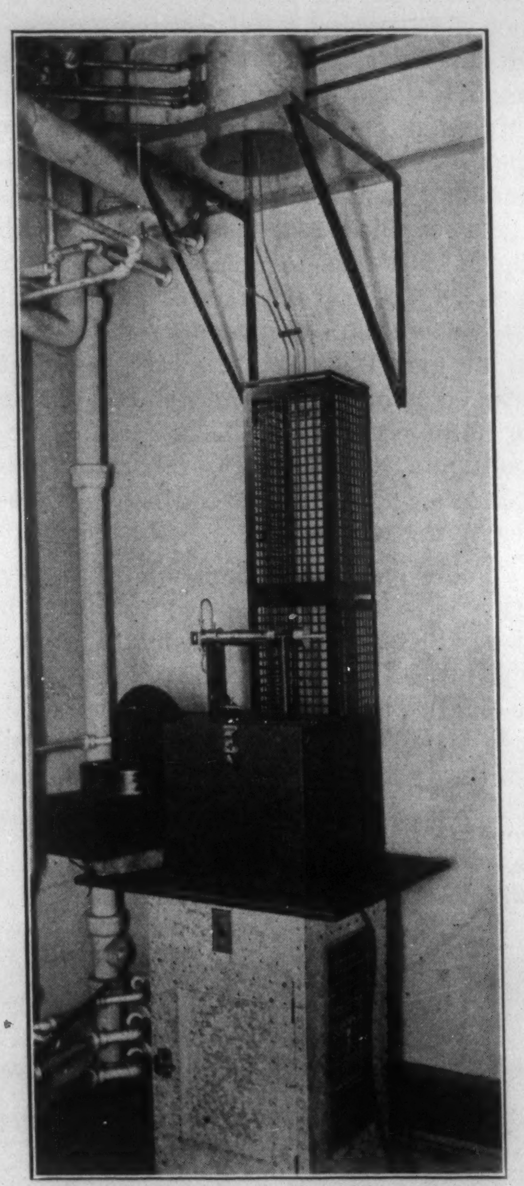

Figure 10—Shearer-Hilger Gas-Type X-ray Tube and Installation for Crystal Analysis

The Phillips Lamp Works of Holland now builds several modifications of the hot-cathode tube primarily for use in Europe. For one type used for diffraction work several extra filaments of both flat, spiral and line type, replaceable targets, very thin windows of metal or Lindemann glass, etc., are supplied. This tube must be attached to pumps and liquid air traps.

The type of power plant now practically universally used for X-ray work is the oil-immersed, closed core, alternating current, high-tension transformer with suitable controls for regulating voltage and current. The Coolidge-type tube is self-rectifying so long as the anode or target is kept cold. In the universal type often used in radiographic work as explained in Section II, the tungsten target becomes white hot so that independent rectification by mechanically rotating disc or Kenotrons is

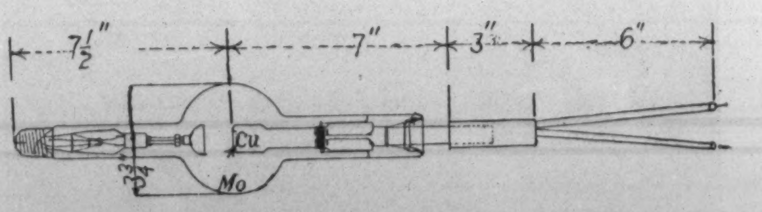

Figure 11—Coolidge-Type X-ray Tube for Crystal Analysis

essential. A rectified unit is also practically necessary for the successful operation of gas-type tubes used in crystal analysis. For radiography in which voltages from 80 to 250 kv. are employed the transformers are grounded in the center and both electrodes of the X-ray tubes are at high potential necessitating insulated water-cooling systems if the target is cooled in cases where high current density is employed. For diffraction or fine structure analyses, molybdenum and copper target tubes are practically exclusively used and voltages above 50 kv. are not required. It is then possible to ground one end of the transformer secondary and the target end of the tube, which may then be connected directly with the city water mains for water-cooling. This also permits placing specimens for examination very close to the focal spot of the target without fear of high tension discharge. The most familiar unit for diffraction work is that produced by the General Electric Company. It consists of a transformer which excites a self-rectifying molybdenum target Coolidge tube at a fixed potential of 30 kv., a filament transformer and a filament current stabilizer besides a slit system for 12 diffraction photographs. Several of the manufacturers of medical X-ray equipment have become interested in chemical, metallurgical and industrial applications of X-rays and are producing excellent rectified power units with positive terminals grounded for the general operation of Coolidge or gas tubes used in research. A new "Standard" power plant designed especially for the operation of copper-target, gas-type tubes is photographed in Fig. 12. The "Keleket" current stabilizer has proved to be a highly efficient and desirable auxiliary equipment for units in continuous usage. Other details of recommended equipment for an X-ray laboratory devoted to metallurgical or other industrial applications are presented in a recent paper by the writer.[2]

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* Part 2 of an article to be published in three parts; for Part 1 see pages 14–17 of this publication, July, 1929.

[1] Professor of Chemistry, University of Illinois.

2. X-Ray Spectra. Following a consideration of X-ray tubes and their operation it is logical to ask concerning the quality of the X-radiation. Since X-rays are like light in every respect except wave-length it follows that an X-ray beam may indeed have many wave-lengths, just as white light is composed of many colors, or it may be monochromatic just as the green line of mercury or one of the yellow lines of sodium. Now the range of wave-lengths (or the wave-length) of the beam is the most important property from the standpoint of utilization of X-rays either in radiography or in fine structure analysis, for in the first place, the penetrating power increases as the wave-length decreases, and consequently this determines the thickness of the specimen which can be tested for either type of information. In the fine structure analysis also the wave-length enters into the most important equation used in the interpretation of results. The selection, measurement and control of wave-length are therefore a fundamental necessity before the tool can be intelligently used for the study of gross or fine structure of matter. This constitutes the science of X-ray spectroscopy. Light is analyzed by a spectrometer employing a prism which produces a spectrum by refraction or differential bending in passing from one medium to another, or a grating of finely ruled lines on glass or metal, which produces a spectrum by diffraction (curling around obstacles). For many years after Roentgen's discovery no one was able to refract X-rays on account of improper experimental conditions, or diffract them because sufficiently fine gratings were not found. Consequently all information until 1913 concerning the quality of X-rays, by which also is meant penetrating power, depended upon measurements of absorption in known thicknesses of materials. In this way it came to be known that X-ray wave-lengths have an order of magnitude of 10^{-8} cm. In 1913 von Laue, reasoning from the ordered and geometrical external forms, predicted that all crystals should constitute three-dimensional diffraction gratings for X-rays if the atoms and molecules were arranged on equidistant parallel planes with a spacing of the order of 10^{-8} cm. The prediction was fully substantiated and an enormous number of gratings were at once available. The Braggs showed at once that a simple equation

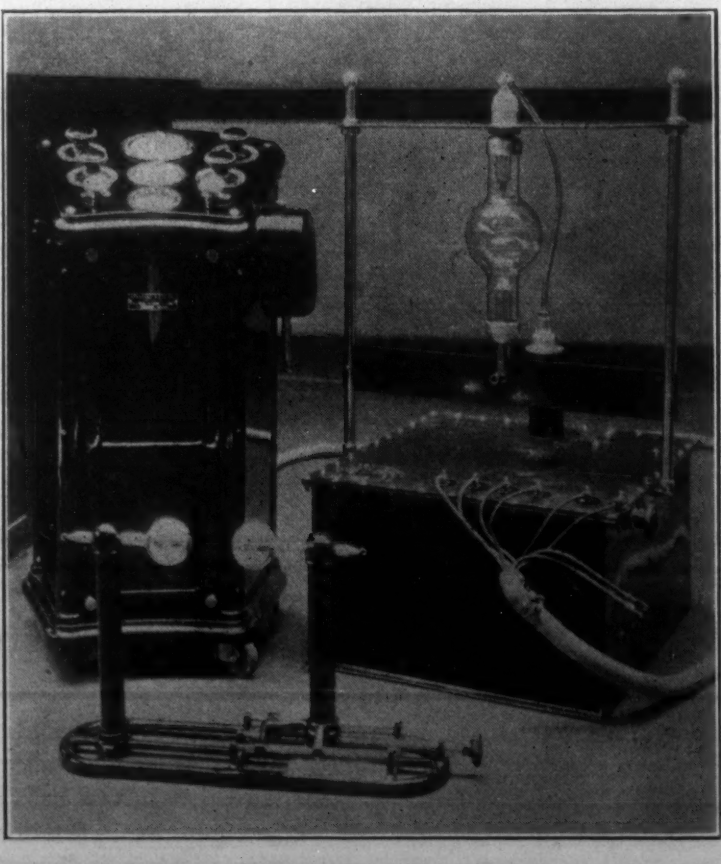

Figure 12—New "Standard" Power Plant for Operating Gas-Type X-ray Tubes for Diffraction Studies

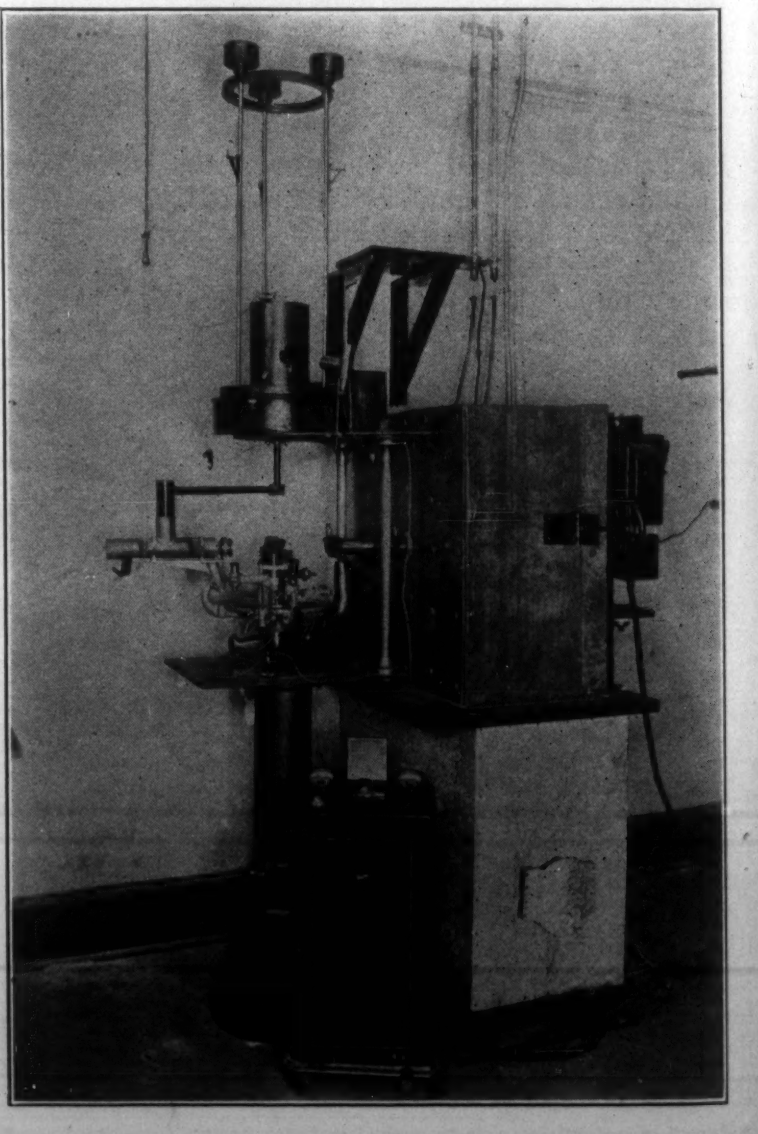

Figure 13—Precision X-ray Ionization Spectrometer for the Measurement of Wave-Lengths

exactly analogous to that for the diffraction of light by optical gratings applied for X-rays, namely,

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[2] *Ind. Eng. Chem.*, **20,** 1381 (Dec., 1928).

$$n\lambda = 2d \sin \Theta.$$

Here n is a whole number expressing the order of the spectrum, λ is the wave-length of X-rays, d is the grating constant (or the distance between members of a set of parallel atomic planes in the crystal) and Θ is the angle of incidence of the beam upon this set of planes. In some cases the beam may impinge upon the face of a crystal and act as though it were reflected, just as light is reflected from a plane mirror. The reflected beam also makes equal angles with the face of the crystal, so that it is readily seen that the total angle between the primary and the reflected or diffracted beam is $2\,\Theta$. An X-ray spectrometer is an instrument such as that pictured in Fig. 13 for experimentally enabling the measurement of an angle, Θ or $2\,\Theta$, upon which is mounted on a rotating table a crystal with a known value of d. From this crystal only a single definite wave-length corresponds to each value of Θ. The composite result is that the X-ray beam is resolved into a spectrum which is registered on a photographic plate or by means of an ionization chamber. The latter depends upon the fact that X-rays ionize gas in a closed chamber, and the ionization current is measured by an electroscope or quadrant electrometer. A reading is made at each setting of the crystal and the spectrum is plotted as ionization current against Θ.

There are four kinds of X-ray spectra: general or continuous, characteristic emission, absorption and ionization. The general radiation characterized by many wave-lengths forms a continuous spectrum. An important feature is that the short wave-length limit λ_e is very sharp and is determined solely by the voltage, V, on the X-ray tube by the rigorous equation

$$Ve = hc/\lambda_e,$$

where e, h and c are constants, respectively, the charge of the electron, Planck's action constant and the velocity of light. The general spectrum is therefore independent of the material of the target.

When a tungsten target tube is operated below 69,300 volts, a continuous spectrum is obtained, but above this voltage there appear superposed upon the general radiation sharp lines or peaks at definite values of Θ or λ as shown, for example, in Fig. 14. These constitute the K-series emission lines which in their positions are characteristic for rhodium. At larger angles other series of lines appear, constituting the L, M, N, etc., series. These sharp line spectra are essentially alike in number of lines and relative intensities for all the elements, but the wave-lengths are characteristic of the kind of material in the target. The greater the atomic number of the metal, the shorter the wave-lengths; as a matter of fact, when the square roots of the reciprocal of the wave-lengths of a given spectral line are plotted against the atomic numbers, a linear relationship is shown—the so-called Moseley Law. For metallurgical applications of X-rays, the K series or shortest characteristic rays are by far the most important. There are four principal lines, γ, β and the doublet α_1 and α_2, of course always superposed on a background of continuous radiation. These four lines will not appear singly but are excited only above a critical voltage defined by

$$V = \frac{hc}{e\lambda_{\text{crit. abs.}}}.$$

The critical absorption wave-length, which is also characteristic and is determined by interposing an absorbing screen of a material in the beam, is only very slightly shorter than the γ line. The values in Ångström units (1 A. U. = 10^{-8} cm.) of characteristic K-series wave-lengths for a few of the metals most commonly used as targets are as follows:

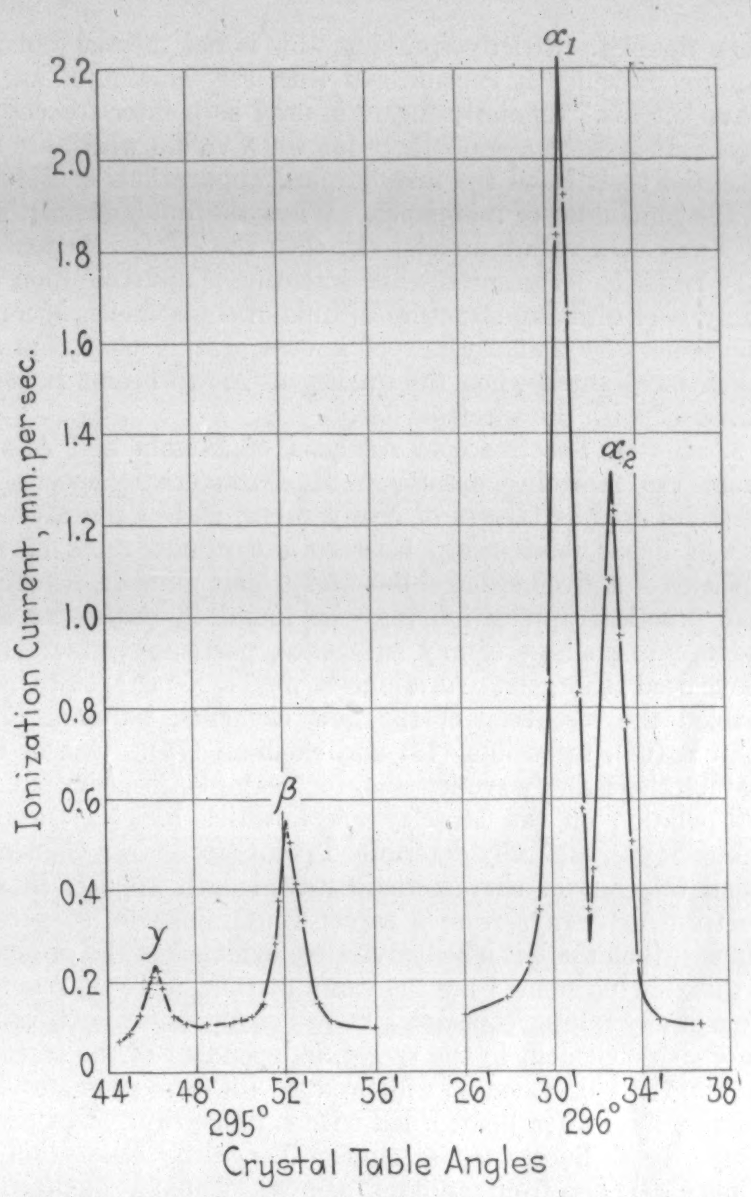

Figure 14—K-series Characteristic Emission Spectrum for Rhodium (Ionization Spectrometer Curve—the Peaks Appear as Sharp Lines on the Photographic Plate)

		Crit. Absorption	~~α~~ γ	β	α_1	α_2
24	Chromium	2.0663	2.0670	2.0804	2.2848	2.2889
26	Iron	1.7405	1.7406	1.7527	1.9323	1.9365
29	Copper	1.3776	1.3780	1.3893	1.5373	1.5412
42	Molybdenum	0.6184	0.6197	0.6312	0.7078	0.7121
74	Tungsten	0.1781	0.1794	0.1844	0.2088	0.2135

It is evident from the foregoing description of spectra that in all cases the beam is polychromatic though the characteristic emission lines if generated will be for the most intense. Such a polychromatic beam is used in radiography, since an accurate knowledge of wave-lengths is not required, but in only one of the more important methods of crystal fine structure analysis. In $n\lambda = 2d \sin \Theta$, it is practically necessary with unknown d to know λ unless recourse is taken to other mathematical and projection methods. It is essential, therefore, to have some method of selecting from the array of wave-lengths, a single definitely known value for the best methods of analysis. This may be done quite satisfactorily by using a double spectrometer in which a first crystal is set at a fixed position to reflect a ray with a definite wave-length. However, this is cumbersome and much intensity is lost before the beam infringes upon the unknown specimen. Another method is to use a filter of such an element that its critical absorption edge will come between the β-line and the α-doublet. Now the critical absorption wave-length is such that shorter rays are absorbed very much more than rays longer than this value. For example, a filter of zirconium has a critical absorption wave-length of 0.6873. This lies between the β and α_1 wave-lengths of molybdenum; hence the filter absorbs the γ and β lines and most of the general radiation but lets through the α-rays which are so much more intense than all others that in essence the beam is really a close doublet. Strictly speaking, this is not monochromatic, but no difficulty is encountered with the doublet of known wave-lengths. Similarly nickel is used as a filter for copper rays. It is these α-doublets of known λ values which are the essential tools in all the metallurgical applications considered in the remainder of this paper. When the fundamental laws of X-ray spectra are understood, then the X-rays themselves may be taken for granted while attention is directed upon the analysis of ultimate structure of unknown materials, in much the same way that crystals of known grating constants are taken for granted when the quality of X-ray beams is being measured with the spectrometer.

3. X-Ray Spectroscopic Analysis of Metals and Alloys. From the foregoing discussion of characteristic spectra of elements used as targets of X-ray tubes, and of the Moseley law of linear relationship between the square roots of frequencies of a given spectral line and atomic number, it follows that practical application may be found in *qualitative* and *quantitative analysis* of any substance, particularly metals or alloys used as targets. As a matter of fact, X-ray spectra have enabled the discovery of the new elements, hafnium (72), illinium (61), masurium (43) and rhenium (75). One of the characteristic line wave-lengths, for example, is predicted by interpolation on the Moseley graph which has been drawn through experimentally determined points for known elements. When this line of characteristic wave-length appears in the spectrum of X-rays from a target containing the suspected element, then there is incontrovertible evidence of the presence of this new element. By the same method analysis may be made of any sample containing known elements simply because every single element in the target, independent of the state of combinations or valence, will produce its own characteristic emission lines when bombarded with cathode rays, as primary X-rays, or as fluorescent secondary X-rays by absorption of primary X-rays from another source. Thus a qualitative analysis of great sensitiveness down to amounts as small as 0.05% is possible, and this may be made quantitative by comparison of the line intensities with those for spectra made with known ratios of constituents in a mixture or alloy. However, the same type of information is obtained from optical spectroscopic analysis with a considerably more simple technic. It is necessary only to strike an arc or spark with the specimen for analysis as an electrode and then to photograph the spectrum of the radiation with prism or grating spectrograph. Consequently, as a routine method of analysis of metals and alloys the optical method is preferable to the X-ray spectroscopic method, since the preparation of the sample as target and the evacuation and adjustment of the X-ray tube are more difficult procedures, perhaps limiting the X-ray method to research. Furthermore, the optical method is equally as sensitive if not more so than the X-ray spectra. In recent experiments in the writer's laboratory a comparison was made between optical and X-ray spectroscopic analysis of lead containing a few thousandths of a percent of several other metals. It was possible easily to detect with only a small spectrograph one part in 2 million by the presence of the "raies ultimes," or persistent rays characteristic of the various impurities. For the very light elements such as aluminum, the X-ray method of analysis is nearly precluded on account of the very long characteristic rays; whereas in a study of aluminum in foods one part in ten million is sufficient to produce a characteristic line in the ultraviolet. In general it may be concluded that analysis of metals and alloys from X-ray spectra is not so important a branch of the science as are the gross and fine *structure*, since in these cases no other method is available, whereas optical spectra yield the same analytical information. In some cases as in new elements or where optical spectra are far too complicated, analysis by the remarkably simple X-ray spectra may be a very great advantage.

4. Fundamentals of Crystallography. In the foregoing sections attention has been given primarily to the fundamental properties of X-rays which are to be used subsequently simply as a tool in the analysis of fine structure of matter. The crystal grating of known constant by which it is possible to analyze X-radiation and measure wave-lengths has been taken more or less for granted. It is now appropriate to take the radiation for granted and to inquire into the reasons for the satisfactory action of crystals as gratings and for the fact that the analysis of X-ray spectra from each crystal leads directly to the interpretation of how a particular crystal is built from ultimate atomic units.

Entirely apart from X-ray data a systematic science of crystallography has been developed which serves as the basis for rational interpretation of X-ray data.[3] The steps in the development of this information may be briefly summarized as follows:

(*a*) The important properties of a crystal visible to the eye are the planar bounding faces and the symmetry The first logical step is to measure the *angles* between faces with the goniometer. In order to express then the positions in space of these planes relatively to each other it is essential to derive a system of coordinates. The planes may then be indexed in terms of their intercepts upon the axes of a system of coordinates; upon each axis a unit distance is chosen and then the distances from the origin of the given plane along the 3 axes is measured; the reciprocals of these intercepts are then the indices of the plane. Thus a plane intersecting the X-axis at unit distance from the origin and parallel to the Y and Z axes has the intercepts 1, α, α and the indices 100 (see Fig. 15). Now an immense amount of experimentation has proved that all angle measurements and indexing of plane faces are accounted for by 7 systems of coordinates (Fig. 16). In other words, there are 7 *Crystal Systems:* triclinic, monoclinic, orthorhombic, tetragonal, hexagonal, rhombohedral (often classed under hexagonal) and cubic.

(*b*) As a further result of the experience of 200 years it is now definitely assured that the indices of all the plane faces of crystals are always small whole numbers (i. e., 100, 321, 568, etc.)—the law of rational indices. If this is true then only a definite *lattice* in 3 dimensions formed by the intersection of three sets of parallel planes can explain the rational intersections on axes. These lattices are, of course, considered to be built on the above 7 systems of coordinates, and there are 14 of these spacial patterns geometrically possible (Fig. 17).

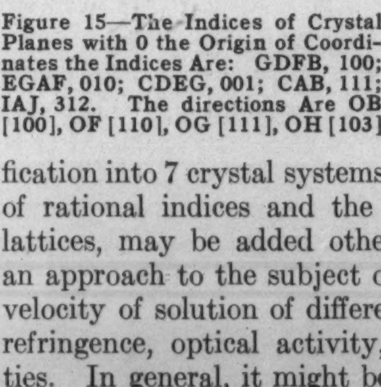

Figure 15—The Indices of Crystal Planes with 0 the Origin of Coordinates the Indices Are: GDFB, 100; EGAF, 010; CDEG, 001; CAB, 111; IAJ, 312. The directions Are OB [100], OF [110], OG [111], OH [103]

(*c*) To the systematic classification into 7 crystal systems, the experimentally founded law of rational indices and the consequent hypothesis of space lattices, may be added other types of information enabling an approach to the subject of symmetry. Some of these are, velocity of solution of different crystal faces, etch figures, birefringence, optical activity, piezo- and pyroelectric properties. In general, it might be expected that 2 crystals, which gave identical measurements of angles between faces indicating identical disposition of planes, should also have identical properties. It soon becomes evident, however, that the formal classification of crystals thus made has not been extended far enough. Mark points out that angle measurements class both barium anti-monyl tartrate and calcium molybdate as

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[3] For an excellent account see Mark, *Z. Metallkunde*, **20**, 342 (1928).

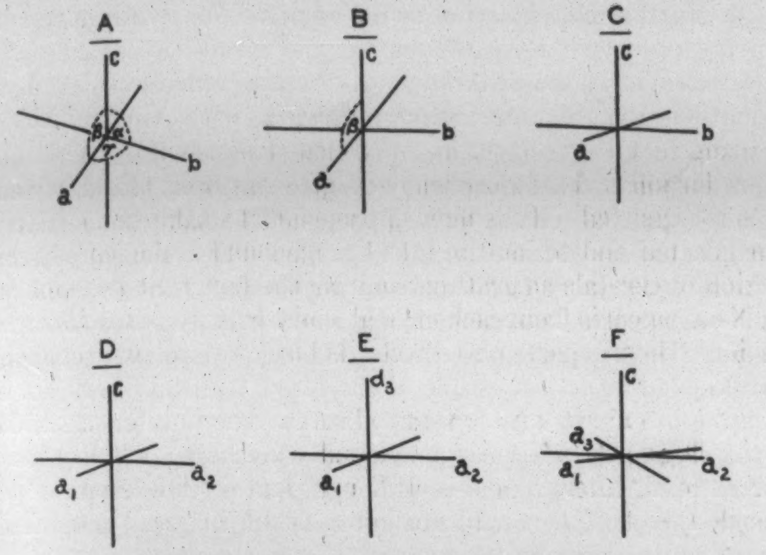

Figure 16—Axes for Crystallographic Systems

- A, Triclinic, $a \neq b \neq c$; $\alpha \neq \beta \neq \gamma \neq 90°$
- B, Monoclinic, $a \neq b \neq c \neq$; $\alpha = \gamma = 90°$, $\beta > 90°$
- C, Orthorhombic, $a \neq b \neq c$; $\alpha = \beta = \gamma = 90°$
- D, Tetragonal, $a = b \neq c$; $\alpha = \beta = \gamma = 90°$
- E, Cubic, $a = b = c$; $\alpha = \beta = \gamma = 90°$
- F, Hexagonal, $a = b \neq c$; $\alpha = \beta = 90°$, $\gamma = 120°$

(The rhombohedral division is sometimes classed as a seventh system)

tetragonal, but this in no sense explains why one has optical activity and the other has not. Account, therefore, must be taken of different symmetries.

(*d*) The symmetry of an object is an expression of the fact that the object has equal properties in different directions. Two positions of a crystal, in which the equivalent directions may be brought into coincidence, say by a simple rotation around an axis, are not distinguishable by any physical-chemical means. Now the following simple symmetry operations may be performed to bring equivalent points in space into coincidence:

1. Axes of symmetry (cyclic operation). Points in crystals may have 1-, 2-, 3-, 4- or 6-fold axes by which is meant coincidence of equivalent points by rotation of 360° (every point has this identity operation), 180°, 120°, 90° or 60°. The fact that there is no 5- or 7-fold axis is further indication of a space lattice structure.

2. Plane of symmetry (mirror operation), in which points on one side of a plane are mirror images of points on the other.

3. Center of symmetry or a combined rotation and reflection across a plane perpendicular to the axis.

When now these symmetry operations are combined in every possible way, using the 7 systems of coordinates, it develops that there are *32 point-groups* which define *32 crystal classes* in terms of symmetry. A combination of goniometric and physical measurements make it possible to classify crystals as to system and as to the finer subdivision of class or point-group. But it is to be observed that this is still a macro-classification, and the idea of the lattice, except as an explanatory hypothesis, or of the ultimate units from which crystals are built does not enter in.

(*e*) The final step in the further refining of classification of crystals was taken as a result of the work of Schoenfliess in 1890, with the 3-dimensional lattice theory and the idea of *atoms* at the points of the lattice as a basis. In other words, by combining the 32 classes of symmetry around a point with *translation* in 3 directions to other equivalent points, arranged according to a definite spacial pattern (the lattice), at a distance of the order of 10^{-8} cm. or atomic dimensions apart, other symmetry operations involving this translation become evident, namely 2-, 3-, 4- and 6-fold *screw* axes of symmetry, involving rotations about and translations along an axis, and glide planes of symmetry in which a figure is brought into coincidence by reflection in a plane combined with translation of a definite length and direction in the plane. These were called by Schoenfliess "microscopic symmetry elements." When these are included in the process of placing each of the 32 point-groups at the points of the 14 lattices, the result is a total of 230 combinations or *space-groups*. The definition of a crystal by its space-group is unique. A recent extension of the space-group theory by Weissenberg takes into account the existence in space of the molecule (in the sense of Avogadro) defined as "island point-group," "dynad" and "micro-building unit."

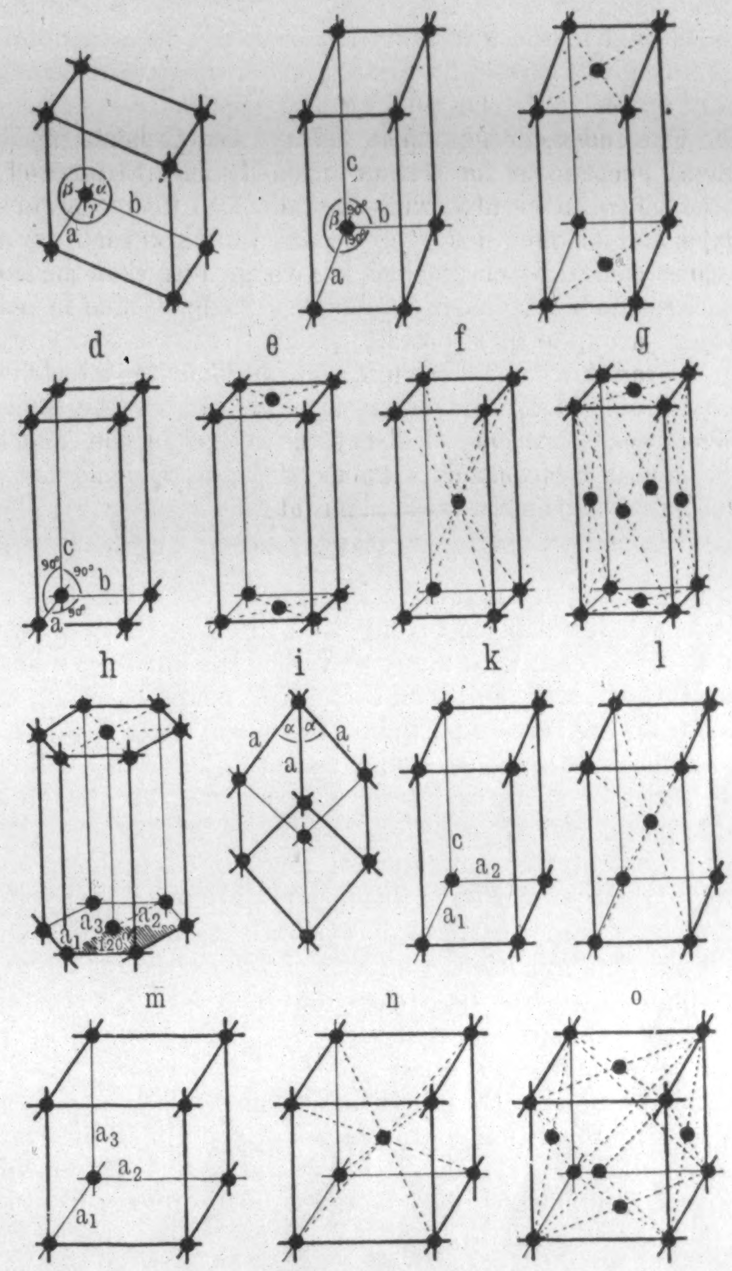

Figure 17—Space Lattices

- a, Triclinic
- b, Simple monoclinic
- c, End face-centered monoclinic
- d, Orthorhombic
- e, End face-centered orthorhombic
- f, Body-centered orthorhombic
- g, Face-centered orthorhombic
- h, Hexagonal
- i, Rhombohedral
- k, Simple tetragonal
- l, Body-centered tetragonal
- m, Simple cubic
- n, Body-centered cubic
- o, Face-centered cubic

It is obvious in the macro-classifications depending upon reflections of visible light by different faces and other physical measurements, why this final refinement depending upon the arrangement in space of *atoms*, and the differentiation between axes and screw-axes of symmetry was impossible. Herein lies the great province of X-rays, as first predicted by Laue in 1913, with wave-lengths of the same order of magnitude as these lattice spacings. X-ray studies of fine structure have thoroughly confirmed the geometrical theory of space-groups, so that now, *vice versa*, the theory of space-groups is an indispensable aid in the interpretation of X-ray spectra obtained from any given crystal in terms of the ultimate fine structure of that crystal.

5. The Interaction between X-Rays and Crystals, and the General Procedures for Determining Ultimate Structure. It is obvious from the foregoing discussions of the properties of X-rays and of the theory of crystal building that crystals must act as diffraction gratings for X-rays and that the interference phenomena of X-rays in a crystal may be used to derive the space-group of that crystal, particularly if the X-ray wave-lengths are known. The simple and fundamental interference equation of the Braggs connects wave-length, the spacing between one set of identical crystal lattice planes, and the experimental measurements of an angle, Θ, of incidence (or $2\,\Theta$ of diffraction) upon these planes,

$$n\lambda = 2d \sin \Theta.$$

This means that constructive interference of a ray of single wave-length takes place in only one direction from a set of planes. If a beam with many wave-lengths infringes upon or passes through a crystal, then each set of planes d_1, d_2, d_3, etc., selects from the beam a particular ray of wave-length λ_1, λ_2, λ_3, etc., at the angle Θ_1, Θ_2, Θ_3, etc., to reflect. The result will be a whole series of spots or interference maxima on the photographic plate.

Regardless of the experimental method of analysis (considered in the next section of this paper) the information vouchsafed by interference patterns of crystals is essentially the same. This is the determination of a series of values of d for different sets of planes by use of the Bragg equation. Now if a crystal is really a lattice, it follows that planes of 3 sets in the principal directions will enclose a small unit cell—the smallest possible subdivision which has the properties of the visible macro-crystal and which by repetition or translation of itself in all directions actually builds the crystal. It is the size of this fundamental architectural unit which may be determined directly from the experimental values of d_1, d_2 and d_3—the respective edge lengths of the small parallelopiped. This presupposes some previous information about the crystallographic system, whether the axes are at right angles or not, or are of equal length or not. As previously indicated, this may easily be obtained by goniometer measurements of angles between faces. But if optical data are not available, the angles between the axes and axial ratios may be measured using X-rays and a crystal mounted on a goniometer head just as readily as by the optical method.[4] Assuming this to be the process employed, the steps in analysis are as follows:

1. Goniometric determination of crystallographic system.

2. Determination of dimensions and volume of unit cell.

3. Determination of the number of atoms or molecules in each unit cell. This involves a measurement of the density of the crystal and the use of the volume of the unit cell in the following formula:

$$n = \frac{\rho V}{Mm},$$

where n is the number of atoms (of an element) or molecules per unit cell; ρ is the density; V is the volume of the unit cell (d^3 for a cubic crystal, or in general

$$V = \text{abc}\,\sqrt{\sin^2\alpha + \sin^2\beta + \sin^2\gamma - 2\cos\alpha\cos\beta\cos\gamma}$$

where a, b and c are edge lengths, and α, β and γ the angles enclosed by the edges); M is the atomic or molecular weight, and m is the absolute weight of the hydrogen atom (1.663×10^{-24} g.).

4. Further classification as far as possible according to symmetry observed, measurement of the intensities of lines, appearance or non-appearance of certain reflections, and the identification of interference maxima with the indices of planes.

5. Application of the theory of space-groups. Each of these space-groups is characterized by certain diffraction criteria, such as the apparent halving of spacings due to non-appearance of odd order ($n = 1, 3, 5$, etc.) interferences. Screw axes and glide planes can be detected; for a screw axis causes all orders of reflection from the plane normal to it to disappear except that corresponding to a multiple of the screw translation, as, for example, in quartz with a trigonal screw axis only the 3rd, 6th, 9th, etc., orders appear. Glide planes halve whole sets of planes hko, where h + k is odd. A great service has been performed by Astbury and Yardley[5] in tabulating and graphically representing these criteria.

6. Determination of the symmetry of the molecule from the space-group of the crystal, the number of entirely unsymmetrical molecules theoretically required and the number of molecules per unit cell actually found.

7. An analysis of the structure factor from intensity measurements, defining the positions within the unit cell of the diffracting centers, and even of the symmetry and positions of atoms in molecules if these are the lattice units. This is the most difficult, least direct and yet the most interesting stage in crystal analysis. Briefly put, the process consists in assuming certain values for parameters and upon the basis of known laws of scattering and interference in calculating from these the theoretical intensity of reflections from a set of planes. These results are compared with observed intensities, and the process of trial and error continued until there is an agreement. Bernal has likened the process to the solution of a cross-word puzzle. The cell and space-group provide the square and pattern, the atoms the letters and the intensities the clues.

8. A coordination and test of the completed structure with other known physical and chemical properties, such as atomic or ionic radii, optical activity, polarization, etc.

In the field of metals and alloys this process of interpretation is not so complex, fortunately, as is true in the analysis of organic compounds with large molecules. The metals are all elements with the simplest types of ultimate structure, the great majority being cubic. As will be shown later, some of the alloy phases are extremely complex and the unique analysis of constitution and structure has required the utmost ingenuity of skilled X-ray metallurgists.

6. Crystal Chemistry. It is entirely to be expected that with the growing mass of information concerning the ultimate constitution and structure of matter, particularly in the solid crystalline state, a rational systemitization of chemistry should result. For the properties of materials in the solid state should depend not only on the kinds of atoms or molecules, but also on the plan of arrangement in space, the unit of structure (atoms, simple or complex ions and molecules) and the kinds of forces holding the units together.

All crystallized substances may be divided into four main classes:

	Unit	Binding	Example
1 Ionic	Simple and complex ions	Electrical attraction between ions of opposite signs	Na^+Cl^-
2 Homopolar	Atoms, such as carbon	Sharing of electron pairs	Diamond
3 Molecular	Molecules	Residual electric fields	Organic paraffins
4 Metallic	Positive ions and electron gas	Attraction between ions and electron gas	All metals and most alloys

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[4] See paper by Clark and Yohe, *J. Am. Chem. Soc.* (in press), in which a unique analysis of optically active phenylaminoacetic acid was made entirely with X-rays and without any previous information.

[5] *Phil. Trans. Royal Soc.* (London), **224A**, 221–257 (1924).

The establishment of the fact that metal crystals are composed of positive metallic ions at the points of lattices held in position by a free electron gas, or in a sense an inter-penetrating lattice of free electrons, is a result of X-ray analysis. The properties which characterize the metallic state are a consequence of this general structure: opacity, due to free electrons with selective reflection in the infra-red; electrical conductivity inversely proportional to the number of free electrons; soluble in acids where hydrogen ions absorb free electrons; moderate to high melting points; moderate hardness increased by alloying; elastic but yield by slipping on glide planes.

The analysis of ultimate structure not only explains rationally the characteristic behavior of metals and alloys, but enables the prediction of properties not otherwise measurable; the importance of the X-ray diffraction method in the science of metals becomes immediately apparent when the types of information obtainable are tabulated.

7. Types of Metallographic Information Obtainable from X-Ray Diffraction Data. From the foregoing development of the subject it might be concluded that the lattice type and unit cell dimensions of metal and alloy crystals, together with the consequent explanation of certain properties, are the only facts to be gained from X-ray diffraction data. Suppose that we know that a whole series of samples of metal has exactly the same lattice structure, characteristic of iron or copper, etc. Is there any further differentiation possible upon the basis of X-ray diffraction patterns? Following is a tabulation of the principal types of information, each of which will receive discussion in this paper, which are possible in the field of metals and alloys:

a. Crystalline or non-crystalline.

b. Crystallographic system, space-group, unit cell dimensions, parameters of atoms or molecules.

c. Deduction of crystal unit (atom ion, molecule), of size of unit, of type of binding and of general properties of solid to be expected.

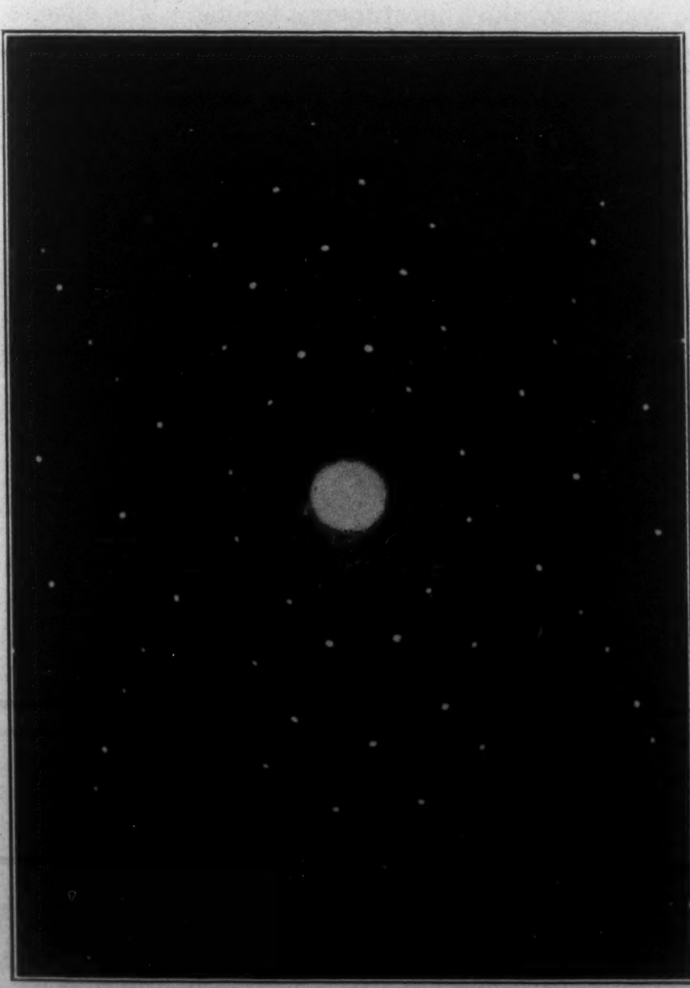

Figure 18—Typical Laue Pattern: Single Crystal of α-Iron with Beam Parallel to [110] Direction (Positive Print)

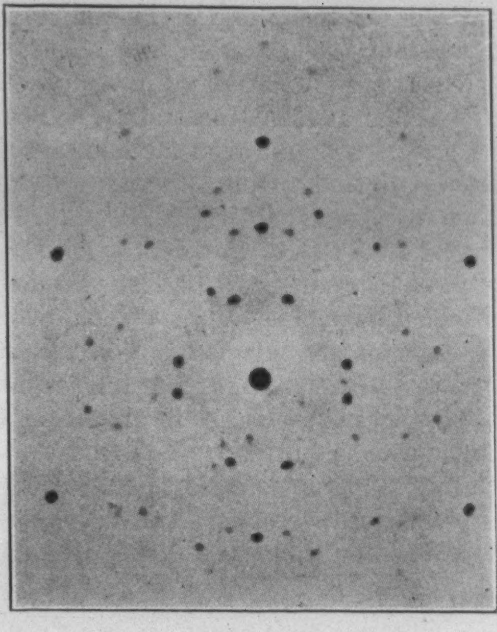

Figure 19—Typical Laue Pattern (Westgren): Single Crystal of $CuMg_2$, with Primary Beam Parallel to [001] (Negative Print)

d. Chemical identity, chemical and crystallographic changes and stability.

e. Allotropic modifications.

f. Type and mechanism of alloy formation.

g. Single crystal or aggregate.

h. Crystallographic orientation of single crystal or of grains in aggregate.

i. Random or fibered aggregate and relative degree in intermediate stages.

j. Grain size in an aggregate (particularly in colloidal range).

k. Internal strain or distortion.

l. Extent of deformation and mechanism of fabrication in rolling, drawing, etc.

m. Analysis of effect of heat treatment, grain growth, control and mechanism of recrystallization, and the establishment of scientifically correct annealing technic.

n. Differentiation between surface and interior structure.

4. Experimental X-Ray Diffraction Methods

1. Details of Methods. Since the original experiment of von Laue in 1913 confirming the prediction that crystals should act as diffraction gratings for X-rays, a considerable number of experimental technics have been devised for spectroscopy and for crystal analysis. Of these, five are practically exclusively used at the present time in obtaining the various types of information from diffraction patterns outlined in the preceding section. The essential variables are whether the X-ray beam

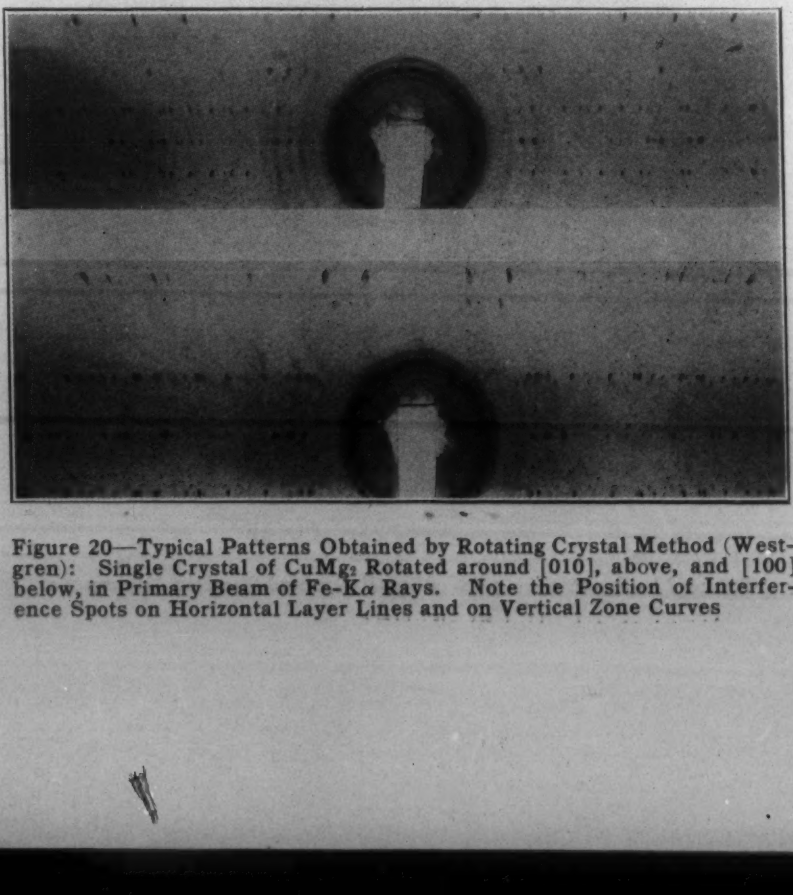

Figure 20—Typical Patterns Obtained by Rotating Crystal Method (Westgren): Single Crystal of $CuMg_2$ Rotated around [010], above, and [100] below, in Primary Beam of Fe-Kα Rays. Note the Position of Interference Spots on Horizontal Layer Lines and on Vertical Zone Curves

is polychromatic or monochromatic (in reality the close $K\alpha$ doublet) and whether the specimen is a single crystal, or a powder or aggregate of many small grains. Since this paper is not designed to be a handbook of methods, it will be sufficient to compare and contrast the approved methods by the following rather complete tabulation (Table I). A typical result of each method is shown in Figs. 14, 18, 19, 20, 21, 22, 23 and 24.

2. The Crystal Analysis of Powders. By far the greater part of X-ray metallurgy utilizes the last two methods in the table, both of which depend upon a specimen of many crystal grains. If these grains are sufficiently small they will be oriented in every possible direction, and enough will be turned so that one set of parallel planes will be in proper angular position to reflect a monochromatic primary X-ray beam; other grains will be oriented at the proper angle to enable reflection from another set of planes, and so on. Thus the photographic film registers a whole series of diffraction lines, each corresponding to one set of planes. Thus, if the beam is defined through pinholes, the diffraction beam from each family of planes will be a hollow cone which intercepts the photographic film as a circle. The complete pattern is therefore a series of concentric rings (Fig. 23), whose number, intensities, pattern and spacings calculated from $n\lambda = 2d \sin \Theta$ are characteristic of a single crystalline substance. These facts were discovered independently in 1917 by Hull in America and Debye and Scherrer in Europe.

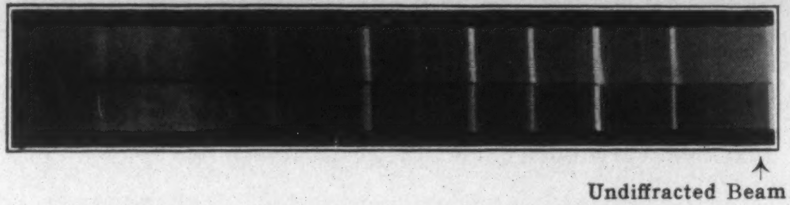

Figure 21—Diffraction Spectrum of α-Iron by Hull Method, Typical for Powders or Random Aggregates
All metals with body-centered cubic lattices give the same pattern of lines

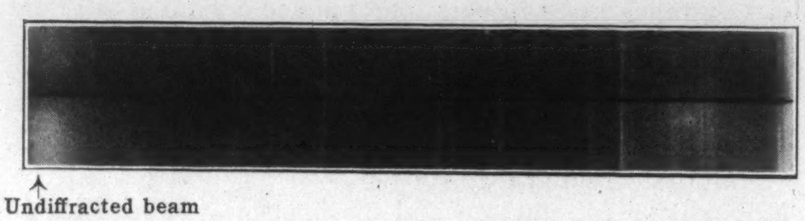

Figure 22—Typical Diffraction Spectrum for Crystal Powders or Aggregate (Platinum)
All face-centered cubic metals give this pattern of lines. Compare with Figure 21

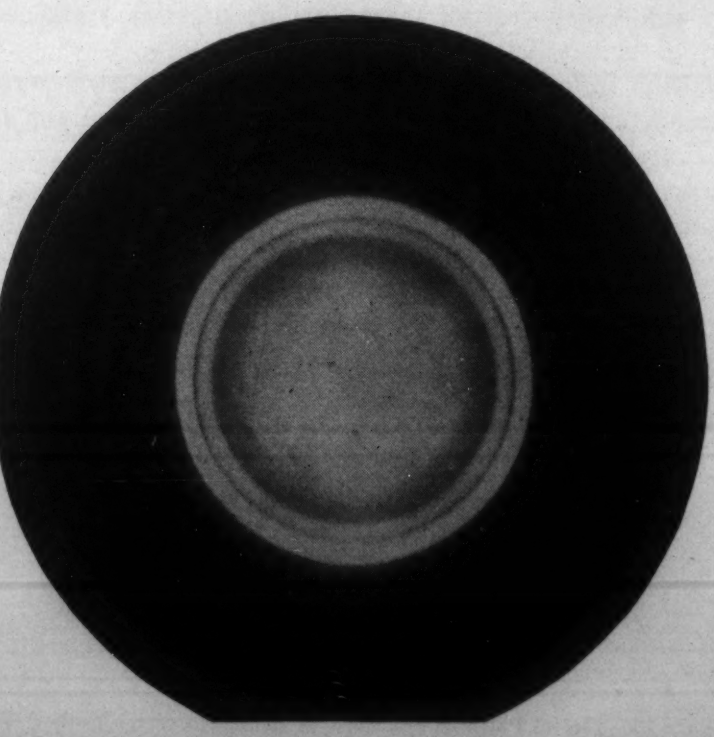

Figure 23—Pinhole Diagram of Small-Grained Random Aggregate of α-Iron

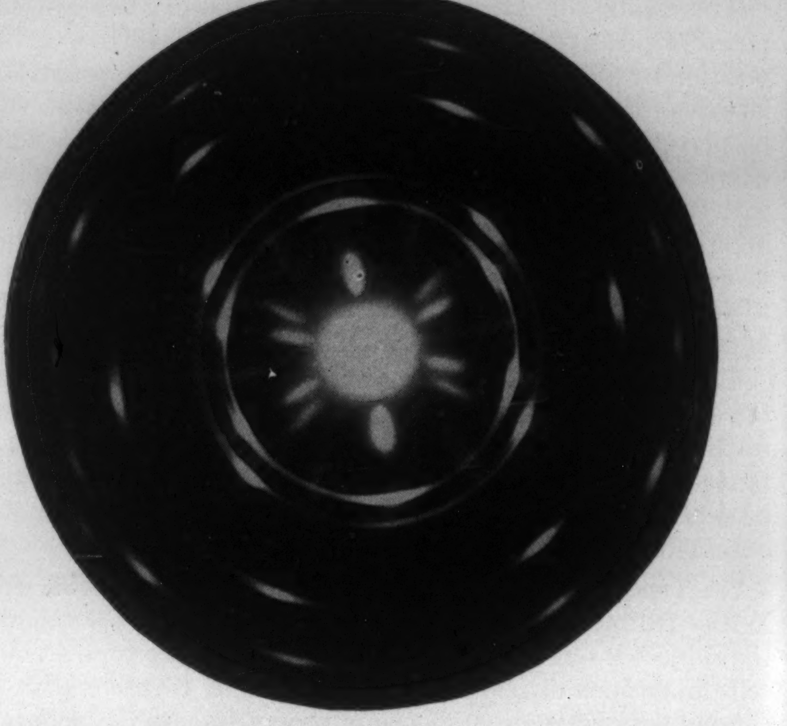

Figure 24—Monochromatic Pinhole Pattern for Cold-drawn Aluminum Wire, Showing High Degree of Fibering
The interference maxima lie on Debye-Scherrer rings and on hyperbolas above and below equator

In the types of cameras employed ordinarily for the crystal analysis of powders the complete rings do not appear, but only a section through the equator of the diffraction circles (Fig. 21 corresponds to Fig. 23). The cylindrical specimen as a fine powder in a capillary tube or an aggregate as a ribbon or wire is adjusted perpendicular to the primary beam and the diffraction pattern is registered on a film coaxial with the specimen. The intersections with the narrow film of the interference cones are in a series of curved lines (practically straight if a slit is used as in the Hull technic).

With such a pattern of lines from a large number of reflecting sets of planes, interpretation is very straightforward for the cubic system to which most metals belong. The spacings corresponding to each of the lines is calculated and then the process involves identifying each with the indices of the planes. This is accomplished by the use of quadratic equations relating $\sin^2\Theta$ for each line with the integral number variables h_1, h_2, h_3, corresponding to the whole number indices of planes. For the cubic system, for example,

$$\frac{4 \sin^2\Theta}{\lambda^2} = \frac{1}{a^2} (h_1^2 + h_2^2 + h_3^2)$$

where a is the edge length of the unit crystal cell. Similarly for the other two of the more common metal lattices,

$$\frac{4 \sin^2\Theta}{\lambda_2} = \frac{h_1^2 + h_2^2}{a^2} + \frac{h_3^2}{a_3^2} \left(\text{axial ration } \frac{a_3}{a}\right) \text{ tetragonal;}$$

$$\frac{4 \sin^2\Theta}{\lambda^2} = \frac{4}{3a^2} \left(h_1^2 + h_2^2 + h_1 h_2 + \frac{h_3^2}{a_3^2}\right) \text{ hexagonal, etc.}$$

Now for a cubic crystal with the results from the above expression it is possible to identify further the type of cubic lattice, i. e., whether simple, body-centered or face-centered. The structure factor clearly indicates that if all possible values of h occur, the crystal is simple cubic (of which there are no examples among pure metals); for the body-centered lattice Σh (the sum of the three indices) must be even and only the following reflections will appear: 110, 200, 211, 220, 310, 222, 321, 400, etc. For the face-centered cubic lattice the indices, h_1, h_2, h_3, must be all odd or all even as in 111, 200, 220, 311, 222, 400, etc. These structures will be illustrated in the next section of this paper. The spectrum patterns for the various types of cubic crystals are diagrammatically presented in Fig. 25.

In systems of lower symmetry than cubic (in which only the cube edge length need be known) the quadratic calculations

Table I

Method	Laue	Bragg	Rotating crystal (Schiebold-Polanyi)	Powder (Hull-Debye-Scherrer)	Monochromatic Pinhole (Fiber)
X-ray beam	Polychromatic	Monochromatic	Monochromatic	Monochromatic	Monochromatic
Beam definition	Pinhole (Fig. 31 without filter)	Slit	Pinhole	Hull, slit; D.-S., pinhole	Pinhole (Fig. 31 with filter)
Specimen	Single crystal	Single crystal	Single crystal	Powder or random aggregate	Any—fibers particularly
Mounting	Fixed according to definite crystal direction	Oscillation; reflection from face or transmission; successive settings of angle in ionization spectrometer	Rotated around principal axis; mounting on goniometer head for proper orientation	Fixed, in small tubes, threads, wires, ribbons, etc.	Fixed with fiber axis oriented, over pinhole and beam transmitted perpendicular
Usual registration	Flat photographic film	Flat or cylindrical film; ionization chamber	Flat or cylindrical film with crystal at center	Narrow film bent in arc with specimen at center	Flat film, perpendicular to beam
Pattern	Symmetrical spots each from different set of planes and particular value of d, λ, Θ, Figs. 18, 19	Line spectrum from single set of planes, Fig. 14	Diffraction spots lying on layer lines, parallel horizontal with cylindrical film and hyperbolas with flat film. Fig. 20	Line spectrum, each line corresponding to different sets of planes. Figs. 21, 22	For random aggregate concentric rings (Fig. 23) or diagram 360° in azimuth; for fibers layer line pattern like rotating single crystal. Figs. 24, 27
Interpretation	Calculation of spacings according to spots. Assignment of indices with assistance of stereographic or gnomonic proportions. Estimation of relative intensities	Calculation of spacings for set of planes involved in particular orientation ($n-\lambda = 2d \sin \Theta$) and thence from 3 experiments size of unit crystal cell. Determination of missing orders, etc., in aiding toward structure factor	Measurement of identity period from layer lines by $I = n\lambda/\sin \mu_n$ and exact size of unit cell. Straightforward indexing of diffraction spots on layer line. Comparison with space-group criteria	Calculation of spacings for lines. In simpler cases assignment of indices from $\sin^2\Theta$ data, and unit cell dimensions. Measurement of line breadths for particle size	Same for powders. Identity period along fiber axis from $I = n\lambda/\sin \mu_n$. Orientation of planes in all fiber particles from positions of interference maxima on Debye-Scherrer rings
Chief uses for metals and alloys	Symmetry, indices and intensities for assignment of space-group. Practical determination of orientation as of large grains with respect to surface of sheet	Occasionally used to determine or check lattice spacing	Commonly used for determining uniquely crystal structure and constitution where single crystals are available	Used in the great majority of cases of study of metals and alloys (single crystals unavailable) for crystalline structure, allotropy, qualitative and quantitative analysis, purity, grain size from line breadths, etc.	Same for powders or random aggregates. Determination of actual state of any specimen, such as degree of fibering, internal strain, etc., and of the effect of any process such as working or heat treatment; thus for the control of industrial processes and as a method of specification
Modifications	Unsymmetrical patterns			Bohlin-Westgren method has slit, flat sample and film on same circumference permitting focus and rapid exposure by reducing absorption of rays in specimen to a minimum	Cylindrical film with axis perpendicular to beam or coaxial with beam. Reflection from surface at fixed angle (Fig. 32); back reflection (described in later section)

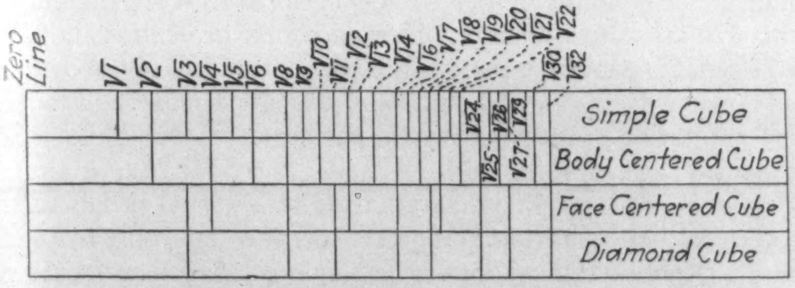

Figure 25—Powder Diffraction Patterns by Which Types of Cubic Lattices May Be Identified

may become increasingly difficult, particularly when the crystal system is unknown. Numerous criteria have been set forth but most useful probably is the graphic method of Hull and Davey[6] for the hexagonal, rhombohedral, tetragonal and partially the orthorhombic systems. For each system the logarithms of the spacing d calculated for each set of planes are plotted against axial ratios. The experimental data are plotted to the same logarithmic scale and then moved over the graph until a match is found, thus identifying system and axial ratios as well as planar indices for each interference.

The following facts are obvious in the interpretation of these line crystal spectra:

a. Only definite lines in a definite pattern correspond to a pure crystalline substance.

b. Foreign lines indicate the presence of other crystalline substances as impurities; each entity produces its own spectrum if present in sufficient quantity (above 0.2 to 1 % usually) and the comparison of intensities is a method of quantitative analysis.

c. Solid solution is indicated by no change in the pattern of lines of a pure constituent, but in a shift in position of the lines, toward smaller angles (nearer the zero main beam) if the lattice is expanded by the addition of foreign atoms, or to larger angles if contracted. In many cases the lattice spacing is linearly related to atomic percentage of constituents of a solid solution alloy.

d. The powder method may be made very accurate in evaluating the lattice constant of a pure substance and from this the *ideal density* of the material. The value for tungsten so obtained has been of utmost value in vacuum tube applications where tungsten filaments are employed.

e. The widths of the diffraction lines serve as a means of determining grain size in the specimen as will be demonstrated in a later section.

f. Any departure of the powder or aggregate from purely random arrangement, which results in continuous diffraction circles or lines of uniform intensity, is manifested by the patterns. Thus if the grains are too large to permit the probability of random arrangement, the lines become spotted and dashed due to reflection from individual grains. (Fig. 26) In general the grain diameter must be smaller than 10^{-3} cm. to prevent this. Most metals with grains which will pass through

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[6] For example, *Phys. Rev.*, **17**, 266, 549 (1921).

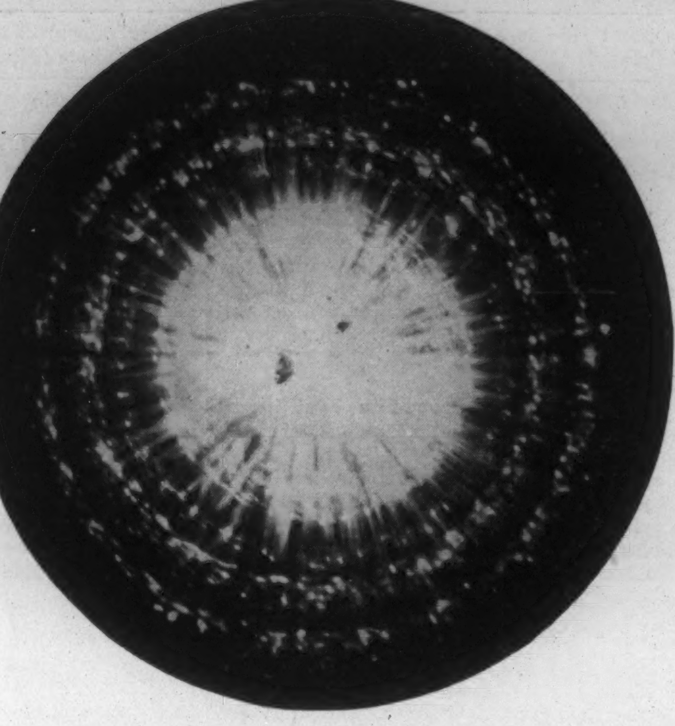

Figure 26—Pinhole Diagram of Coarse-Grained Random Aggregate (Inter-crystalline Corroded Duralumin)

a 200-mesh sieve will give uniform lines. Again if the grains are sufficiently small, but are oriented in some *preferred* direction, as by some deforming force, some lines may become shortened, or disappear or assume localized intensity maxima. This process of fibering will be now considered.

3. Fiber Structure. Fig. 27 taken by the monochromatic pinhole method is reproduced as an example of the structure of a natural fiber, asbestos. This mineral is not a single crystal since otherwise it would give a Laue pattern of symmetrical spots. But neither is it constituted of grains in random arrangement since this would mean a pattern of concentric uniformly intense rings. It may be seen, however, that circles may still be drawn through the diffraction maxima although the more prominent loci are hyperbolas. These would be parallel, straight horizontal lines (as in Fig. 20) if a cylindrical film had been used instead of a flat one. In this mineral, therefore, the grains are oriented in a common direction with respect to the fiber axis. The pattern is typical of a *fibered* aggregate. Now a fine-grained metal aggregate may be made fibered by rolling or drawing in one direction, as shown by Fig. 24 for cold-drawn aluminum wire. The desirability of a pattern 360° in azimuth is at once apparent if the degree of fibering is to be estimated and if the actual *location* of the symmetrically placed maxima is to be used in the determination of the *mechanism* of deformation by mechanical work as explained in a later section. A fiber diagram has a great advantage over an ordinary powder pattern and this is that a measurement of a *lattice spacing*, viz., the atomic plane periodicities along the fiber axis, may be made independently of any assumption as to crystal system or planar indices. It is necessary only to measure the distances e_1, e_2, e_3, ...e_n of the vertices of the hyperbolas (or of the straight layer lines on a film which had been bent on a cylinder coaxial with the specimen) from the central zero point of the main beam. Knowing the distance from specimen to film, a, the diffraction angles μ_1, μ_2,....μ_n may be calculated since the tangents are e_n/a. The identity period or spacing along the fiber axis is then simply calculated from $I = n\lambda/\sin\mu_n$ where n is the number of the layer line (1, 2, 3, etc.). Thus identically the same value is obtained from all the layer lines. For the other lattice spacings it is necessary, of course, to interpret the pattern exactly as in the powder method since the Debye-Scherrer circles may still be evident. The *degree* of perfection of preferred orientation is, of course, indicated at once by the patterns, since there may be a continuous transition between the random proof of concentric circles and the perfect fibering of sharp horizontal layer lines.

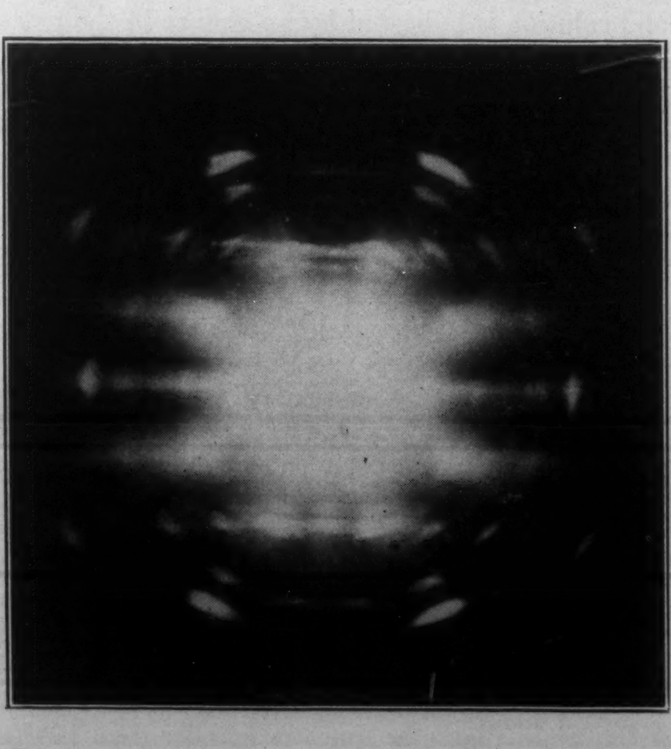

Figure 27—Typical Pinhole Pattern for Nearly Ideal Fiber (Asbestos) Showing Both Hyperbolas and Circles

While this method has come to be most generally associated with the fiber state, it follows, of course, that it is only a special case of the Laue method and of the powder method. It is generally employed in all of the metallurgical studies involving fibering in fabrication, internal strain, annealing and recrystallization.

4. Single Crystal Methods. Since methods involving the use of single crystals are less frequently used on account of the relative difficulty in obtaining good metal and alloy specimens, the outline in Table I will suffice. The Laue method will receive more detailed consideration in a later section in connection with the determination of grain orientation in sheets. Both the Laue and particularly the rotating crystal methods have been expertly employed in the remarkable work of Westgren and his co-workers in the identification of complex alloy systems such as δ-bronze with 416 atoms per unit cell. In the Laue method since many X-ray wave-lengths are involved recourse must be taken to stereographic or gnomonic projections in order to identify spots with planar indices. Graphical methods such as those of Bernal[7] and Schiebold[8] also assist materially in the interpretation of rotating crystal patterns. It should be noted that the pattern obtained by rotating a crystal around a principal axis is a layer line diagram exactly like that produced by a fiber without rotation. With a fiber, of course, only one such result is obtainable while with a single crystal, three patterns corresponding to rotations around the three principal axes are possible. The angles between these axes may be determined in this process if the crystal is mounted on a goniometer head, since rational clear-cut layer lines are observed only by rotation around principal axes. The three layer-line identity periods give at once the dimensions of the unit cell, regardless of crystal system. The process of assigning indices to the interference maxima lying on the layer lines is usually straightforward. Thus on the equatorial line the index h_3 in $h_1h_2h_3$ is zero; in other words, all indices must be h_1h_20; h_3 must be 1 on the first horizontal layer line, 2 on the second, etc. These maxima lie not only on horizontal layer lines, but also on vertical loci which are zone curves. Schiebold calls these layer lines (Schichtlinien) of the I and II kind. Thus if the first maximum on the equator is due to 100, then the spot on the first layer line lying on the common vertical zone curve is 101; if the second spot on

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[7] *Proc. Roy. Soc.* (London), **113**, 117 (1926).

[8] *Fortschritte Plin. Krist. Pet.*, **11**, 113 (1927).

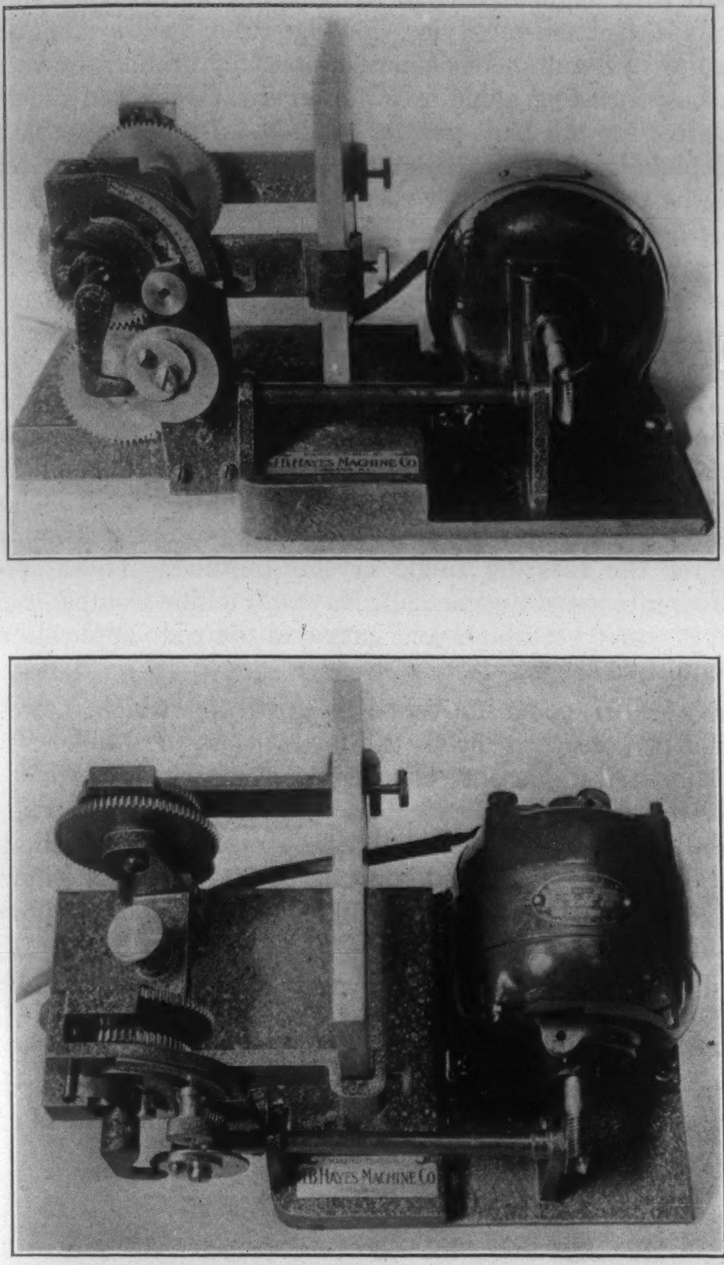


Figure 28—Two Views of Spectrograph for Use with General Electric Diffraction Apparatus, Combining Bragg Oscillating Crystal and Pinhole Reflection Methods

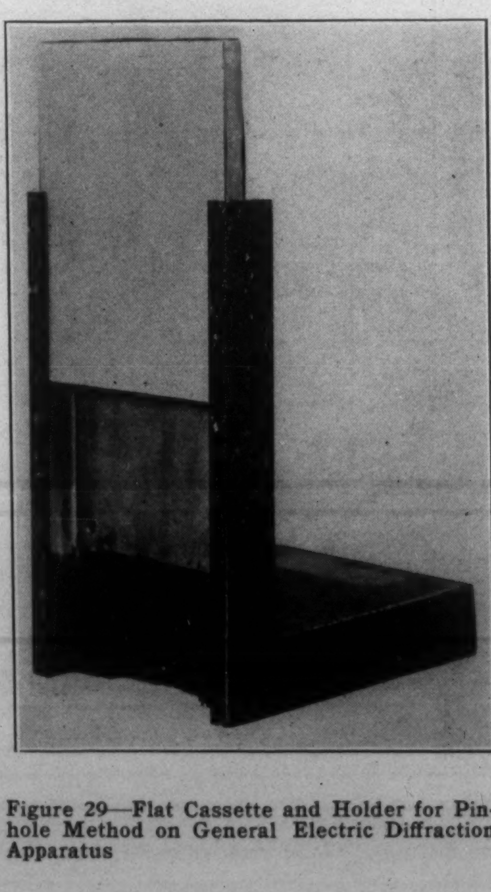


Figure 29—Flat Cassette and Holder for Pinhole Method on General Electric Diffraction Apparatus

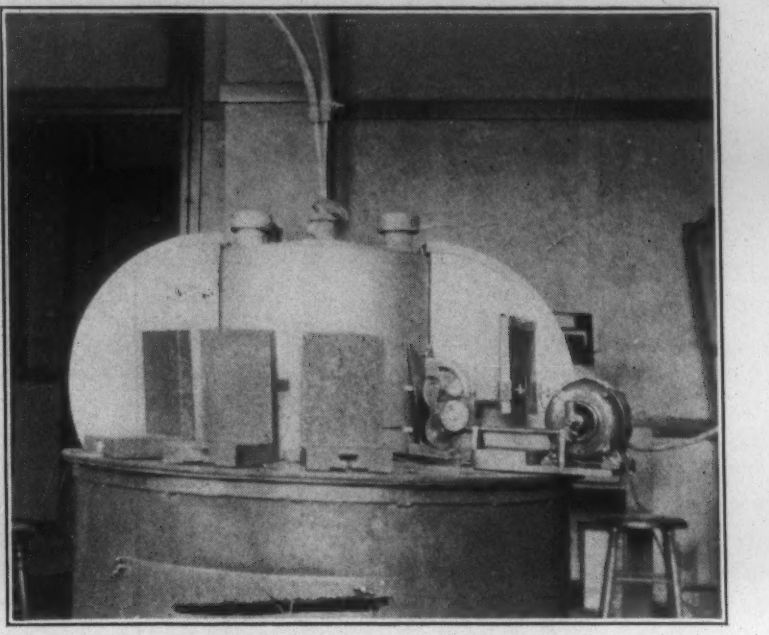


Figure 30—Top of General Electric Multiple Diffraction Apparatus, Showing Water-Cooling Leads for Coolidge X-ray Tube Coaxial with Cylinder, and Quadrant, Flat and Oscillating Cassettes in Position

the equator is 110, the spot above it on the first layer line and the second zone curve is 111. The remarkable simplicity of the interpretations of rotating method patterns is sufficient evidence of its great usefulness and wide application (particularly to complex organic compounds). Two years ago the method was scarcely heard of. It stands as the most useful way of clearing up questions of constitution and structure of complex alloys whenever a single crystal, even though it be only 0.1 mm. in diameter, is available.

5. Diffraction Apparatus. The most familiar and useful appaartus for metallurgical and chemical applications is the multiple General Electric diffraction apparatus. This consists of a transformer operating at a fixed potential of 30,000 volts, with an enclosed filament transformer, an operating switch

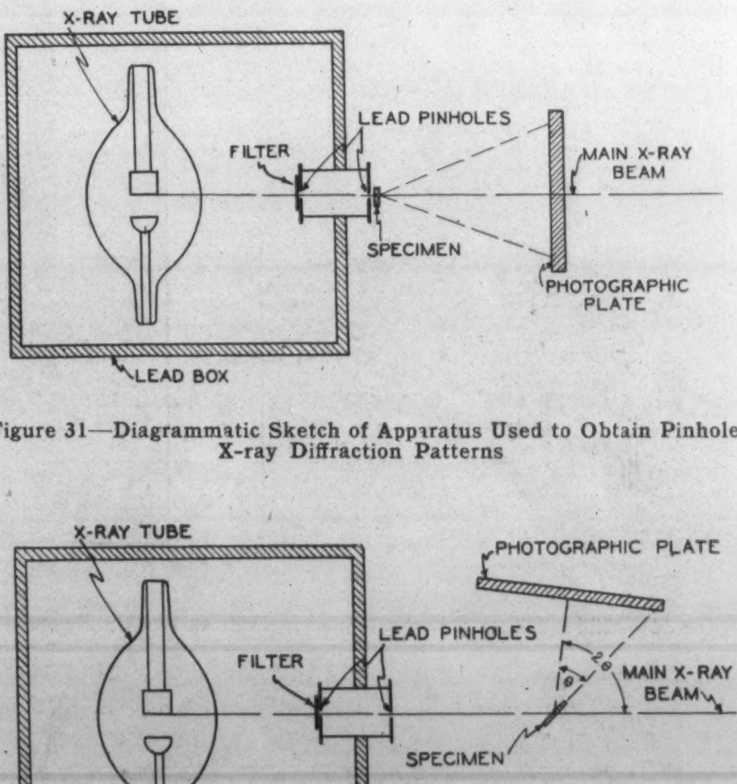

X-RAY TUBE
LEAD PINHOLES
FILTER
MAIN X-RAY BEAM
SPECIMEN
PHOTOGRAPHIC PLATE
LEAD BOX

Figure 31—Diagrammatic Sketch of Apparatus Used to Obtain Pinhole X-ray Diffraction Patterns

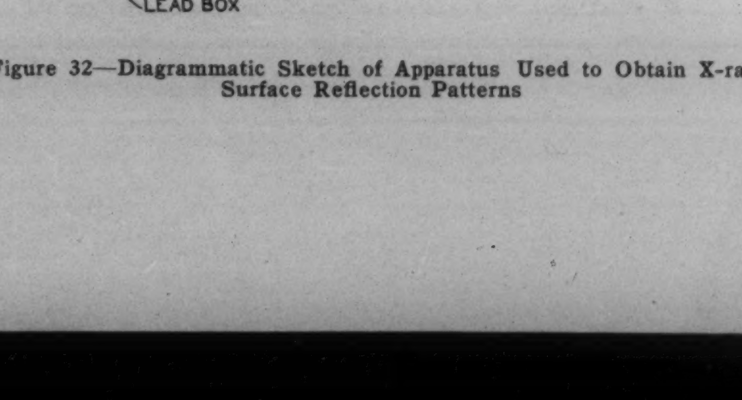

X-RAY TUBE
PHOTOGRAPHIC PLATE
LEAD PINHOLES
FILTER
2θ
θ
MAIN X-RAY BEAM
SPECIMEN
LEAD BOX

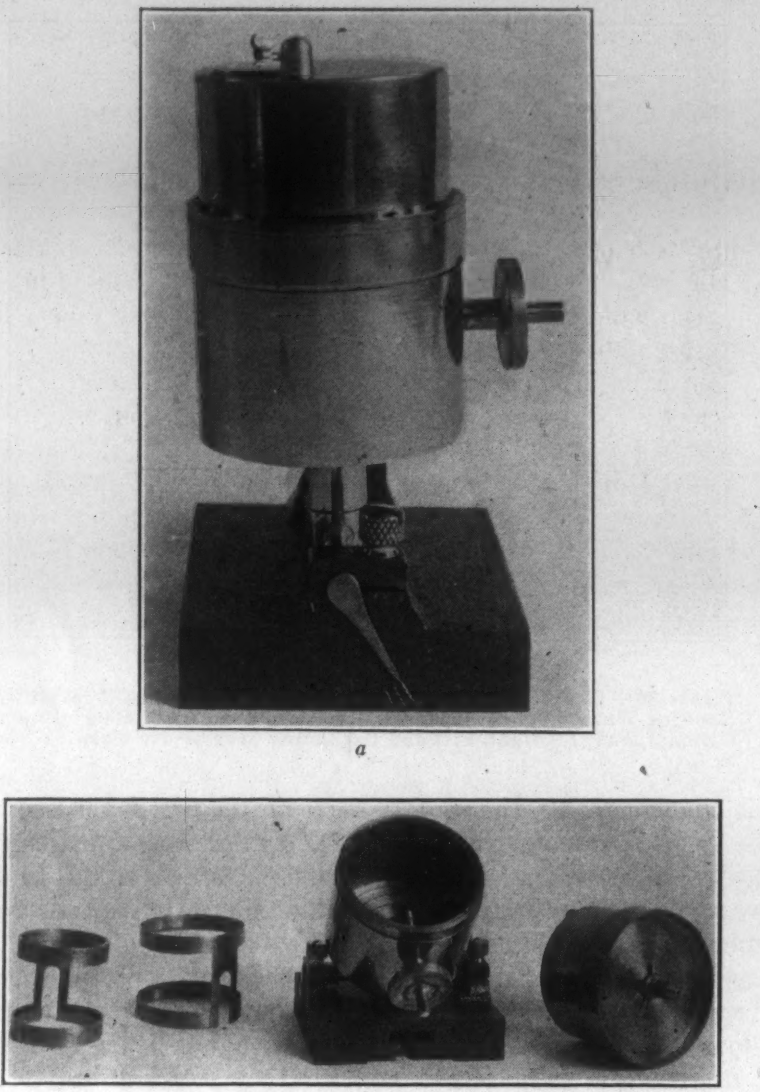
Figure 32—Diagrammatic Sketch of Apparatus Used to Obtain X-ray Surface Reflection Patterns

board with filament current stabilizer, a water-cooled molybdenum target self-rectifying Coolidge tube, a slit system which permits 12 simultaneous exposures radially around the vertical tube at a grazing angle of 5° upon the target and quadrant cassettes for the Hull powder method. Interchangeable slits and pinholes made of bakelite impregnated with lead oxide give the apparatus greater elasticity, since oscillating reflection spectrographs (Fig. 28), flat cassettes (Fig. 29) and other specially constructed devices may also be mounted. In the writer's laboratory every one of the methods including modifications may be used on the General Electric apparatus. Figure 30 shows the table top with quadrant cassettes for the powder method, flat cassettes for the pinhole method (diagrammatically shown in Fig. 31) and a spectrograph combining the Bragg method (oscillation of the specimen) and the pinhole surface reflection method (diagrammatically shown in Fig. 32). Figure 33, *a* and *b*, shows a camera for the Debye-Scherrer powder method, and also for the rotating single crystal method. These special instruments made by the J. B. Hayes Machine Company have been of great usefulness and increased the wide application of the multiple apparatus.

Another ingenious universal spectrograph which, however, cannot be used with the G. E. apparatus, is the Müller-Hilger instrument. It has interchangeable parts which adapt it for all of the methods of crystal analysis. As shown in Fig. 34, *a*, *b*, *c*, it is set up respectively for the Bragg method (oscillating crystal), for the Laue and rotating crystal methods (showing the goniometer head) and for the Debye-Scherrer powder method.

Numerous spectrographs and cameras of all types combining special features have been described in the literature, particularly those of German design and manufacture. Most of these special pieces can be constructed in any good machine shop and especially adapted to the particular needs and interests of each X-ray laboratory.

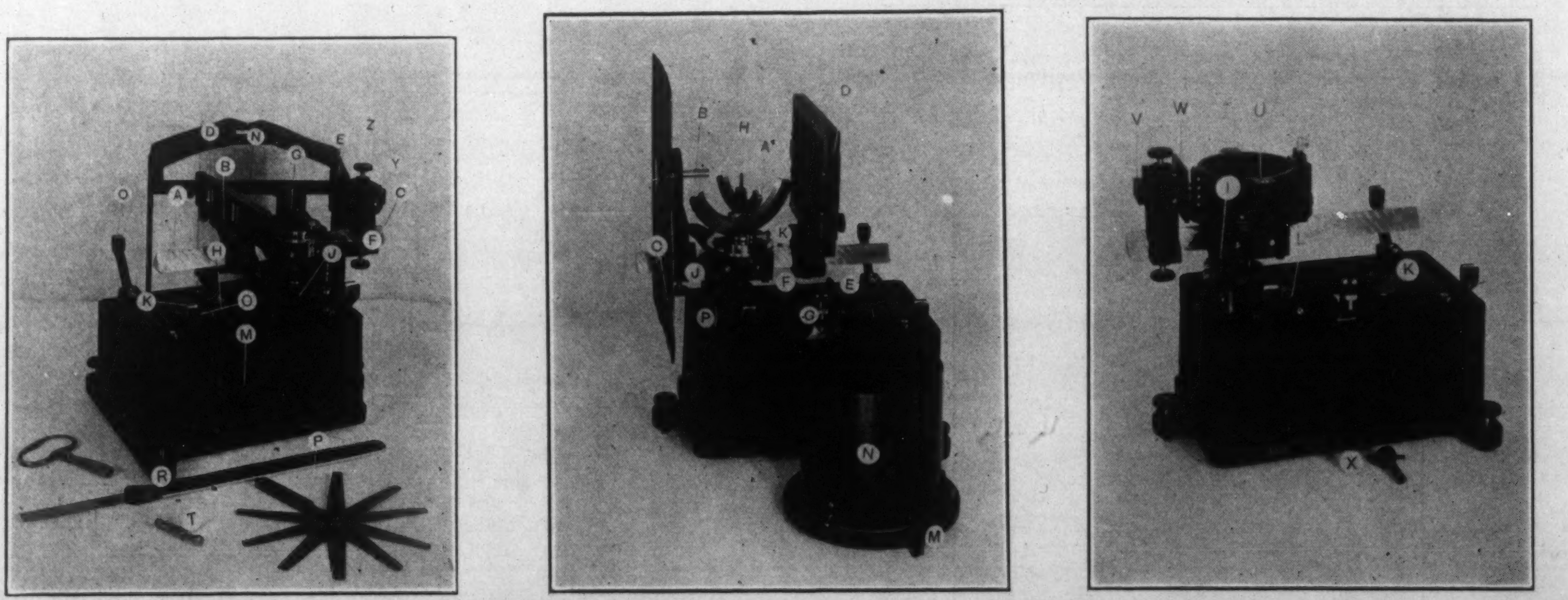
(*To be continued*)


a

b

Figure 33—Two Views of Camera for Rotating Crystal and Debye-Scherrer Powder Diffraction Methods for Use with General Electric Apparatus or Special Units.

The parts (33b) are, from left to right, film holders of 2 sizes, adjustable case with pin hole, and base and clockwork top for rotation and chuck for specimen



a *b* *c*

Figure 34—Müller-Hilger Universal Spectrograph as Set Up Respectively for Bragg, Laue and Rotating Crystal, and Debye-Scherrer Powder Methods

Beryllium

By Menahem Merlub-Sobel[1]

Its individuality recognized as far back as the 18th century, beryllium has nevertheless remained an element of mystery for almost 150 years. Difficult to isolate, its rarity in metallic form made any extended study of its properties and alloys utterly impossible until the past decade which, bringing some small amount of the metal, enabled workers barely to scratch the surface of the field. Now that the problems inherent in isolating the metal have been, to no small extent, decisively conquered, there can be little doubt but that the next few years will bring rapid advances—new uses, new alloys, broad commercial utilization.

Beryllium is not really a "rare element," though generally so classed. It is merely an ultra-sociable cuss—very unwilling to part from its friends, oxygen least of all. And the rarity of beryllium in elemental form has given rise to the quite understandable error that this rarity is the necessary consequence of ore scarcity. In actuality, beryllium ores—beryl particularly—are relatively common, and a recent survey of the known deposits has shown sources adequate for many years to come, at American-delivered prices ranging from $35 to $60 per ton. The equivalent beryllium metal price in the ore therefore varies from 38¢ to 67¢ per pound—by no means so high as to bar commercialization.

Of course, raw ore is but a minor factor in the current cost of beryllium. From something like 87% of alumina and silica associated with it in beryl, BeO must first be separated, and this compound then converted into an electrolyzable salt. Fused electrolysis deposition must follow, and, in one process (the American), there is a remelting to yield massive metal. And even this rather elaborate series of steps represents a high degree of simplification and economy over previous attempts to manufacture the metal.

While pure science did direct considerable effort toward the isolation of beryllium ever since Wöhler first obtained it in highly impure form, the modern automobile and aeronautical era has made the winning of the metal far more commercial a matter. It is this call from technology that explains the simultaneous development of two procedures for manufacturing beryllium, both within the past decade. A milestone in metallurgical and scientific history was reached by one of these—the high temperature electrolysis of alkali and alkaline earth beryllium fluorides. It was developed simultaneously, but quite independently, by Stock and Goldschmidt in Germany and by Dickinson in America, though only the former and their co-workers, now banded in the Beryllium Institute of the firm Siemens-Halske, have carried the process beyond experimental stages. The whole operation is unique in that electrolysis of sodium and barium beryllium fluorides proceeds at the hitherto-unthinkable operating temperature of 1300–1350° C., this being necessary in order to obtain the metal in fused form (its melting point is 1278° C.).

The American procedure, invented by H. S. Cooper and his associates, involves the electrolysis of far less corrosive a salt, and differs also in that the temperature of electrolysis is along more orthodox lines, about 750° C. These advantages are counteracted in part by the fact that the metal is obtained in the form of spangles, which must be pressed and fused together. On the other hand, the German metal runs only about 98% in purity, and a higher grade of material can be obtained only by a similar remelting.

The standard American metal runs well over 99% in beryllium, with iron representing about 0.20% and silicon 0.10%. Certain changes in technique lead to the hope that all or most of the iron will soon be eliminated, which would carry beryllium into the realms of the highly pure metals.

The Atlantic separates not only the processes used, but also the major phases of alloy interest. Whereas our work here has been primarily in the more obvious light-metal alloy field, Siemens-Halske has been active in the study of the alloys of the heavier metals; much of this work has been described in articles by Illig, Masing, Dahl, Kroll and Becker. For the most part, the alloys studied by them have been those of copper, nickel, cobalt and iron. These all show remarkable improvement in properties when heat treated, a copper alloy with 2.39% beryllium showing a Brinell of 100 prior to treatment and then rising to 440 after a 17-hour soaking at 300° C. The tensile strength of untreated metal is approximately 70,000 lbs./in.^{2}; after treatment the order of magnitude is 194,000. Transverse bending strength goes from 77,000 to 310,000, and the yield point rises from 22,500 to 183,000. The elastic limit rise is even more astounding; before treatment 7200 is indicated—after, 65,600. The alloys can be worked and rolled without difficulty prior to heat treatment; afterward, they are hard and tough, their ductility decreasing proportionately.

Nickel and cobalt show much the same general characteristics—a nickel alloy with 2.5% Be will have a Brinell hardness of over 500 after heat treatment. The iron alloys are readily comparable with the standard carbon steels, though this series of alloys has received scant attention as yet as compared with what the subject merits.

Although we, on this side of the Atlantic, have done some work on the heavy alloys, principally those of gold and silver, most of our interest has been in the beryllium-aluminum series, representing the ultra-light alloy field. Added to aluminum in material amounts, beryllium raises the strength of that metal very markedly, and its resistance to corrosion increases just as sharply. Indeed, the high-beryllium region of this series may be appropriately viewed as a ductile form of beryllium, for, with as low as 10% of aluminum, some amount of mechanical working is possible if special precautions are taken, and with the addition of 20% aluminum, the workability problems reach proportions almost in line with other metals of commercial type. The 70 Be-30 Al, upon which considerable work has been done, primarily with a view toward its use in communication devices, shows a tensile strength of the order of 100,000 lbs./in.^{2} in the direction of rolling and 70,000 transverse to it. With a specific gravity of only 2, it exhibits materially greater resistance to salt water and air corrosion than any other of the light alloys, and carries proportionally most of the other qualities of beryllium itself. A further advantage of the beryllium-aluminum series will doubtlessly accrue from the fact that most currently commercial aluminum alloys have a very low elasticity modulus, whereas beryllium has a high modulus of elasticity.

Specifically, the beryllium-aluminum alloys offer interesting possibilities as engine pistons, because of the low thermal expansion of beryllium, approaching that of cast iron. This is particularly so in the aeronautical field, where every ounce of weight is of importance. The same is also true for their moving parts—connecting rods and the like—but here the far greater strength of the beryllium alloys comes into play, so that smaller cross-sections would be necessary for equal strength. Not only in the airplane power plant, but no less in the fuselage proper, beryllium will ultimately offer its services as a component of all-metal planes, and in the structural members of other types. Salt water corrosion normally plays havoc in hydroplanes, and here beryllium alloys should be particularly of value, since they are much more immune to this type of attack than any of the metals now in use for the purpose.

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[1] Formerly Chemical Engineer, Beryllium Corporation of America.

Beryllium, unalloyed, is by no means as limited in its field of usefulness as might seem at a casual glance from its hardness and brittleness. Its low atomic weight makes it of great value in X-ray apparatus—and small plates of hot-pressed beryllium are being used to no small extent in Germany for this purpose. Far larger an outlet for the metal is its potential use in neon-type signs, where its combination of low atomic weight, low specific gravity, high melting point and non-corrodibility makes it ideal for electrodes.

The engineer, always practical, will of course, turn and ask crossly, "How much?" And here again we must admit our ignorance. The present price of the metal, $200 per pound, is, naturally enough, highly artificial. However, with increased demand and manufacture, there is good reason to believe that the metal could be manufactured at less than $5 per pound if, and when, the market absorbed 100 tons or more per annum; this without crediting the metal with certain by-products obtained in the course of its manufacture. For the immediate future, a figure of $34 to $41 is the price expected by the German workers as soon as their operations reach to a ton per year. American facilities, we hope, will also be increased shortly, and then there will be a corresponding sharp cut in price. In any event, whatever the momentary charge, beryllium is not inherently dear; any outlet of material size should bring its cost down into the unit figures. And so little beryllium by weight goes so far in area and volume.

According to "The United States Daily," the new plant of the company, which will be the first in Canada to specialize in manufacture of such products as stainless, heat-resistive steels, is nearing completion at Shawinigan Falls, Quebec, according to a report from the Assistant Trade Commissioner at Montreal, L. A. France, made public on July 9 by the Department of Commerce. The full text of the Department's statement follows.

Stainless steel will be manufactured by a plant at Shawinigan Falls, Que., which is now near completion.

When completed the new factory will provide for the manufacture of alloy steel castings of all kinds including stainless heat-resisting steels, corrosion-resisting steels, wear-resisting steels, carbon steels, specially annealed steels and duriron steels.

The company owning the new plant will be the first in Canada to specialize in the manufacture of such products. Its equipment will include an electric heat-treating furnace and two electric steel furnaces of one-ton and two-ton capacity.

Empire Steel Castings, Inc., Reading, Pa., have recently been incorporated to take over the business and assets of the Empire Steel Casting Company. The company will carry on the business developed by the late company in high grade electric alloy and carbon steel castings. The officials of the new organization are: President, Mr. Frank Hodson; Directors, Mr. Charles Shipman Peyson, Mr. Wallace E. Belcher, Mr. J. A. Osherman, Mr. D. W. Phillips; Secretary-Treasurer, Mr. J. E. Horton. The company has recently completed extensions to the foundry and further additions will be made in the near future.

A Study of the Ikeda Accelerated Test for Determining Endurance Limit

By H. F. Moore and Seichi Konzo, University of Illinois

In the July number of Metals & Alloys, Dr. Gillett gave a very excellent review of accelerated tests for determining endurance limit with special reference to the Ikeda method which uses the change of electrical resistance as an indication of fatigue failure. The resistance method is promising on the grounds that it does not seem unreasonable that the starting of an actual fatigue crack would affect the electrical resistance of metal more than would slip without fracture. As Dr. Gillett points out, the work of the Sperry detector for fissures in rails, which operates on the resistance principle, also gives some hope for the success of the resistance method.

During the past year at the University of Illinois, the writers have been making a study of the Ikeda method, using a testing machine of the rotating-spring type, in which the specimen is held stationary, the leads to the potentiometer are soldered to the specimen, and the problem of electrical contact with the rotating specimen is avoided. Furthermore, it is not necessary to turn flanges on the specimen with small radii at their bases.

The results so far obtained are, of course, purely tentative but they are interesting. They are shown in the accompanying table. In addition to these tests, a rather interesting confirmation of the reliability of the Ikeda test for S. A. E. 1020 steel was obtained. The first tests showed an endurance limit by the Ikeda method about 11 percent *higher* than the endurance limit by long-time tests. Upon examination of records it was found that the particular specimen tried out in the Ikeda test had been subjected to 18,000,000 cycles of stress just below the endurance limit, and that the increased endurance limit was just about what might be expected from such a period of "understressing."

Dr. Gillett, in his review, makes the point that the Ikeda test with its increments of stress necessarily involves understressing and a raising of the endurance limit. This is true, but the period of understressing is very short, less than 10,000 cycles at each increment of stress, and for the most part, the loads applied are well below the endurance limit with a consequent small amount of understressing effect. At any event these preliminary tests do not show any appreciable effect from this understressing.

The time required to carry out one test averaged about $2^1/_4$ hours, including the soldering of connections to the specimen. The resistance was measured by the fall of potential method using a Leeds and Northrup type K potentiometer.

The complete account of this study is now before the Engineering Experiment Station of the University of Illinois for publication as a bulletin. It is planned to continue the work and to make tests on other metals, especially on duralumin, alloy steel, cold-worked non-ferrous metals, and cast iron.

Metal	Endurance Limit Lb. per Sq. In.		Maximum Number of Cycles of Stress in Long-time Tests
	Ikeda Test	Long-time Test	
Armco iron	20,600	22,000	30,025,000
0.52 Carbon steel (Sorbitic)	53,000	56,000	108,987,000
Hardened tool steel	128,000	134,000	5,273,000
Brass, annealed	29,500	30,000	400,000,000
Monel metal "111"	29,000	32,000	700,000,000
Monel metal "K"	39,000	40,000	450,000,000
Copper, annealed	29,800	10,000	400,000,000

Correlated Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

Work on Beryllium and Its Alloys

A full-sized book[1] of some 250 pages and 200 illustrations contains an account of the last ten years' work on beryllium and its alloys in the Siemens' laboratories.

It contains a foreword by A. Stock, an outline of the Siemens' program on production and use of beryllium by K. Illig, an account of the analytical chemistry of beryllium by H. Fischer, and of the occurrence of the ores by M. Hosenfeld. Seven articles by one or more of the three authors last mentioned deal with the thermal reduction of the metal, the decomposition of raw beryl and the preparation of salts suitable for electrolysis, the production of the metal and the direct production of its alloys by electrolysis, the influence of bath composition temperature on the electrolysis and the production of plated coatings of beryllium on other metals by electrolysis from fused baths. Eleven papers by one or more of the following: G. Masing, O. Dahl, C. Haase and E. Holm, deal with the theory of age-hardening on the bases of the Be-Cu alloys, with the constitution, properties and age-hardening of these alloys, with the effect of age-hardening as shown by the behavior on etching, the electrical conductivity, the density and by X-ray spectrograms; with ternary copper-base alloys (CuSn, CuZn, CuAl) containing Be, with the effect of additions of phosphorus on the Be-Cu alloys; and with NiBe alloys.

W. Kroll discusses the Fe-Be alloys and O. von Auwers with magnetic measurements on these alloys.

The whole volume ought to be translated into English not only for the interest of the subject matter itself, but also for the light the exhaustive work on the Cu-Be alloys throws on the problem of age-hardening. We shall make running comment on the volume as a whole without attempting to connect each point with the particular one of the two dozen separate articles in which it occurs.

Analytical methods advocated for determination of Be are based on colorimeter titration with quinalizarin (1, 2, 3, 5, 8 tetra-oxyanthraquinone). Zinc-beryllium alloys up to 3% Be are mentioned under analytical methods but no further description of them is given.

In the extraction of the metal from beryl, the beryl is sintered with an equal weight of Na_2SiF_6 at 650–700° C. and the Na_2BeE_4 extracted with cold water. By successive treatments with NH_3, $Ca(OH)_2$ and HF, raw BeF_2 is obtained which is purified and converted into 2Be 0.5Be F_2, ready for electrolysis.

Since Be has a melting point of about 1285° C. the Siemens' laboratories favor a fused electrolyte operating above that temperature so as to obtain a compact deposit, 1400° C. being the optimum temperature. The oxyfluoride is almost non-conducting in itself and 45 to 50% $BaFe_2$ is added, at which bath composition the current is about 80%. Presence of NaF is harmful. A 90% recovery of Be can be made. The Be is deposited on a water-cooled iron cathode dipping into the fused bath and withdrawn as the deposit accumulates (similar to the manufacture of metallic calcium). The anode is an Acheson graphite crucible with a water-cooled top-plate to prevent oxidation. The cathode current density is 100 to 400 amp./cm². The bath runs at 8 to 10 volts. The fumes are sucked off through an absorption tower, where CF_4, from reaction of fluorine with the anode, is recovered. A photograph is shown of a 25 K.W. reduction pot in operation.

The average cathode deposit contains 0.31% Fe, 0.07% Al, 0.04% C, 99.58% Be by difference.

Beryllium is 17 times as transparent to X-rays as is aluminum of the same thickness, so plates 1 to 2 mm. thick, and 2 cm. diameter, obtained by pressing the metal at a red heat, are used as windows in X-ray tubes. This appears to be about the only commercial use of the metal itself.

The brittleness at room temperature of the purest metal so far obtained would make it necessary to carry out all forging, rolling or drawing operations at high temperatures. Since the metal oxidizes readily at high temperatures, such work would have to be carried out in a reducing atmosphere.

The electrical conductivity is about $^1/_{12}$ that of copper. The specific gravity is about 1.84, i. e., about that of magnesium. It has the highest heat of fusion of any metal, 341 cal./gr.

The metal is rather volatile at temperatures above its melting point. It is stated that no success has been had in attempting to alloy it with magnesium. Beryllium does not amalgamate with mercury.

It is claimed that Be will quantitatively reduce Al_2O_3. Its strong deoxidizing power makes it a possibility for scavenging other metals. It forms carbide on heating with carbon, even below the melting point.

At 500° Be powder combines directly with nitrogen, or at 750° with NH_3, to form nitride. No statement is made as to its trial in steel for nitriding, though in view of the use of aluminum in steel for this purpose it would seem to the abstractor to be worth trying.

By electrolysis in molten NaF, 2Be $0.5BeF_2$ mixtures Be can be plated out on Cu, Ni, Fe, Al, etc. By heating, in most of these cases, surface alloying will take place, producing a surface layer with the properties of the Be alloy.

Electrolysis of AlF_3 and BeF_2 produces AlBe alloys direct. By introducing powdered Cu into the regular bath for production of Be, the Cu is changed to fluoride at the anode and deposited at the cathode with the Be. Alloys up to 20% Cu may thus be made.

A large part of the volume is devoted to the CuBe alloys. The α solid solution field extends from about 2.8% Be at about 860° C. down to about 0.75% Be at 400° C. The slanting solubility line offers possibilities for the duralumin type of heat-treatment. By quenching alloys of 1.5 to 4% Be at 750–850° C. and subsequent re-heating at 250–400° C. the hardness and strength are greatly increased. Maximum hardness is obtained in about a day at 250° C. or about 2 hours at 350° C. Fully hardened (400 Brinell) specimens are not softened by 100 days further heating at 250° C. but are softened at higher temperatures.

The hardening is due to the splitting up of the α solid solution into $\alpha + \gamma$ eutectoid. The eutectoid temperature is 578° C.

In wrought material, strength up to about 213,000 lbs./sq. in. with zero elongation, and in cast material up to 125,000 lbs./sq. in. with 0.5% elongation. Of course by varying the reheating temperature ductility may be gained at the expense of strength and hardness. The heat-treated wrought material appears suitable for springs since the modulus of elasticity of a 3% Be alloy properly heat treated may be brought up to 17,000,000 lbs./sq. in. and a figure of 20,000,000 is also given.

The details of the age-hardening process were studied by microscopic examination, by X-ray methods, by etching behavior and by electrical resistance methods, all discussed in detail.

In the hope of preventing loss of Be by oxidation when added to molten copper containing oxide, pre-deoxidation by phosphorus was tried. The presence of phosphorus accelerates the aging process and makes it occur at lower temperatures.

When up to 3% Be is added to bronze, brass or aluminum bronze, the alloys are still heat-treatable, similarly to the straight Cu-Be alloy. Alloys up to 9% Sn, 18% Zn and 3% Al, plus varying amounts of Be, were studied. Hardness values only are given.

In the Ni-Be system the solid solubility of Be in Ni is about 2.8% at 1150° C. falling to about 1.5% at 800° C. Hence the duralumin type of heat treatment is also applicable here. The hardening agent is in this case the compound NiBe. Quenching alloys of 2 to 2.5% Be from 1000–1100° C. and reheating at 400–450° C. gives a Brinell number of about 600. Other mechanical properties are not given.

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[1] Beryllium—Arbeiten. Wiss. Veröff a. d. Siemens—Konzern, vol 8, no. 1, 1928 (Pub. by J. Springer, Berlin).

Binary Fe-Be alloys can be heat-treated, if the Be content is over 2% Be.

	Brinell Hardness		
Be Content, %	Quenched from 1100° C.	Aged at 520° C.	Annealed at 950° C.
1.21	212	221	212
2.25	241	289	241
2.97	222	353	231
3.00	230	335	252
3.88	263	467	335

Some unknown beryllide is thought to be responsible for the hardening. While it is apparent that the effort was to work with carbon-free material, the actual carbon content is not stated. The addition of Be caused the formation of extremely large grains and the binary alloys are classed as practically worthless. The similarity of Be to Si suggested magnetic study but this showed higher watt loss than with pure iron.

Attention was then turned to addition of Be to other steels, presumably almost carbon-free in most cases, electrolytic or Armco iron being used, though in a few cases scrap steel was used so that the final alloy had about 0.20% C. In a series containing 1% Be and varying Ni showed great effect of sufficient Ni in avoiding large grain size. Steels with 1% Be and over 4.75 Ni had very fine grain. From 4.75 up to 22% Ni, oil quenching from 1100° C. and aging at 450° C. gave about 600 Brinell. At 27–46% Ni the hardness dropped to about 200.

In NiCrBe steel, it took more Ni, when 1% Be was present to produce fine grain, at 12.7% Cr, and 1% Be, there was required 6.25% Ni. The low carbon alloy of 12% Cr, 5% Ni, 1% Be quenched from 950° gave 185,000 lbs./sq. in. tensile strength, 7% elongation, 47% reduction of area, 350 Brinell, while one of 20% Cr, 7% Ni, 1% Be, gave 145,000 lbs./sq. in. tensile, 11% elongation, 7% reduction of area, 275 Brinell. After aging at 500° C. the Brinell rose, respectively, to 670 and 480, both samples being so brittle that no tensile strength figures could be obtained and the elongation was 1% and the reduction of area not measurable in both cases. An alloy of 20% Cr, 9% Ni, 1% Be, 0.20% C only rose from 207 to 257 Brinell on aging after the 950–500° C. heat treatment.

Invar (36% Ni) plus 1% Be (low carbon), quenched from 1200° C. and aged at 500° almost doubled in hardness on aging (150 Brinell quenched 295 aged). The quenched material was soft and workable, having 84,000 lbs./sq. in. tensile, 27% elongation, 46% reduction of area. The aged material gave 159,000 lbs./sq. in. tensile, 5% elongation, 14% reduction of area.

Thus the austenitic steels of the V_2A and invar type become hardenable through addition of Be.

Masing and Dahl find no promise in the addition of $^1/_4$ to $^1/_2$% Be to aluminum or to alloys of the duralumin type. A brief study of the Si-Be system showed no compounds, and of course all the alloys are brittle.

In all this work there seems to have been no special effort to obtain beryllium of high purity or to study the properties of the alloys high in beryllium. Even the properties of the metal itself are largely taken from published results of other workers.

One interesting property of beryllium has been overlooked or unrecorded by the Siemens laboratories, the high modulus of elasticity, which is almost that of steel.[2]

Nor have they commented on the rather remarkable properties of the Al-Be alloys high in Be.[3]

Since the American workers in this field feel that the price of beryllium can be brought down to a much lower figure than the present one (through the use of the chloride bath, with its lower temperature, for production of the metal) just as soon as there is a sufficient demand to justify large scale production, and since, for aircraft uses, it is the high beryllium alloys that are of interest, it would appear that other lines of study than those recorded by the Siemens' workers might be fruitful. Certainly, a metal with the lightness of magnesium, the resistance to atmospheric corrosion of silicon, a melting point above that of copper, and the modulus of elasticity of steel would be useful if it could be fabricated into form suitable for aircraft use.

H. S. Washington[4] has estimated that there is as much beryllium in the world as there is lead or zinc.

A recent personal communication from a South African mining engineer states that in prospecting for gem emerald an area at least 16 miles and probably 30 miles long and up to 3 miles broad has been proved capable of furnishing beryl crystal in quantities and under mining conditions that foreshadow a considerable and permanent commercial output. A considerable tonnage of run-of-mine beryl is now accumulating.

With beryl available, methods for production of the metal pretty well worked out, and prices due to fall sharply when quantity production may be entered upon, the neck of the bottle from the point of view of aircraft use appears to be lack of knowledge of methods of hot-working the metal into sheet, tubing, etc.

One possible use is in the cast form as a piston for use against nitrided cylinders. The hardness of beryllium indicates that it might have a good wear-resistance.

Illig predicts that the production of beryllium at the Siemens work in 1929 will be about a ton. It is to be hoped that the American interests will again take up production of the metal and that in both America and Germany part of the production may be used in a study of the properties of the metal itself and of the high-beryllium alloys.—H. W. GILLETT.

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[2] See H. S. Rawdon, "Discussion," Div. Am. Inst Min. & Met. Eng., *Proc. Inst. of Metals*, 646 (1928).

[3] See "Light Alloys," Bureau of Standards, *Circ.*, **346**, 316 (1927).

[4] H. S. Washington, "The Chemistry of the Earth's Crust," *Jour. Franklin Inst.*, **190**, 768 (1920).

Vacuum Melting for Quality Steel—Why Not?

The goal of all makers of quality steel is steel entirely free from inclusions and from blow-holes. Dr. Herty and his cooperators in the Bureau of Mines and Carnegie Tech., backed up by the steel industry, are making notable strides in the advancement of knowledge of the mode of formation of, and of the mechanism of the elimination of, oxide inclusions.

That work, when completed, will without question make more clear the reasons for details of melting and deoxidation practice in present day open-hearth and electric furnaces and will probably point the way to distinct improvements. It, however, also brings out the fact that there are difficulties and limitations which make it unlikely that the goal, clean steel, can be very closely approached with furnaces operating under atmospheric pressure.

The first stage of the steel-making operation involves the removal of carbon by the addition of iron oxide, the second is concerned with the removal of the excess of iron oxide. The reaction $FeO + C \rightleftharpoons Fe + CO$, being reversible, does not go to completion as long as there is CO pressure over the melt. The higher the concentration of carbon the lower the concentration of ferrous oxide in the melt.

For any temperature, carbon content and CO pressure there is an equilibrium FeO content. A low carbon steel melt will contain high FeO and a high carbon one a lower FeO content. This residual FeO content must be reduced though the agency of Mn, Si, Al or similar deoxidizing agents, all of which form oxides which are with more or less difficulty released from the steel. Those which are not released but remain suspended in the melt form solid non-metallic inclusions when the steel freezes.

The more nearly the reduction of FeO by carbon can be brought to completion, the less FeO will remain and the smaller the amount of inclusions that will be formed on adding the deoxidizers. It is theoretically possible to bring the reaction to completion if all CO is removed from the sphere of the reaction. In other words, if the steel is finished under reduced pressure, the CO being pumped off as fast as it is formed, the FeO content would fall even in a low carbon steel, just as it does when the carbon is increased.

Hatfield[1] comments on the low solubility of oxygen in a high carbon steel.

It is certainly not practical to suggest operating an open-hearth furnace or an arc furnace in a vacuum or under appreciably reduced pressure. With the present development of the high frequency or "iron-less" Ajax Northrup induction furnace, however, it does not appear at all visionary to contemplate actual vacuum melting on a commercial scale.

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[1] W. H. Hatfield, Discussion, *Trans. A. S. S. T.*, **15**, 585 (1929).

Ajax Northrup furnaces of 600 lbs. capacity are operating commercially and the results indicate clearly, first, that much larger furnaces can be operated and, second, that operating costs will be low enough to warrant consideration for the manufacture of quality products on a tonnage scale. Furnaces now available are themselves out of the "toy" class and enough metal can be melted to allow establishing with a high degree of certainty what may be expected in truly large scale operation.

It is not time to try capping an induction furnace, during the finishing period of the heat, connecting a vacuum pump, carrying off the CO and allowing reduction by carbon to go further and eliminate the bulk of the FeO, thus minimizing the work to be done by deoxidizers that leave undesired solid deoxidation products?

Besides allowing reduction by carbon to go further there is a probability that "dissolved" gases, not only oxygen, but also hydrogen, nitrogen, etc., would be so removed that blow holes and "loose structure" might also be avoided.

The experiment seems worth trying, not in a cursory way, to be dropped at the first sign of difficulty, for new difficulties will surely be met, but in a comprehensive series of experiments carried out with a will to do what physical chemistry tells us can be done when we use suitable apparatus in the proper way.

Indications are not lacking that commercial vacuum melting is just around the corner. At the Westinghouse Electric and Manufacturing Company, Yensen[2] and collaborators[3] working with 2-lb. melts under very high vacuum have found that by so balancing the carbon addition made to electrolytic iron that, under the constant removal of CO, the FeO content was presumably eliminated without leaving any carbon in the metal, the magnetic properties were improved far beyond the best figure hitherto obtained with unalloyed iron. With as little as 0.10% carbon, oxide inclusions were almost absent.

Rohn[4] at the Heraeus works in Hanau, Germany, has been developing vacuum-melting technique on NiCr alloys for a dozen years. Starting with a melt of 5 lbs. in 1917 he reached in 1925 one of 4 tons and shows a photograph of a single vacuum-melted ingot of 3000 lbs. In the final paragraph of his article he states that so far he has not needed larger than a 4-ton charge, but that it would be quite feasible to build to-day a 30-ton furnace operating at 1750° C.

For the 4-ton furnace, starting with a cold furnace and a cold charge, only 860 KWH per ton of NiCr alloy is required, measured on the high tension side of the motor-generator.

Rohn not only melts his charges in a vacuum but he pours in vacuum. From his curves the vacuum in melting a $1^1/_2$-ton charge of nickel chromium alloy ranges from about 3 to about 10 millimeters of mercury. The details of the vacuum enclosure for furnace and mold are not described, though he has discussed[5] the water-cooled molds used. Very slow pouring is used so that the ingot will freeze from the bottom up and be continually fed. Forty to sixty minutes are taken to pour a 2-ton ingot. Rohn claims for such castings entire freedom from gas holes, and remarkable freedom from non-metallic inclusions. He estimates that the vacuum fused alloys produced in 1928 by the Heraeus Company amounted to 110 tons.

He claims that the vacuum process applied to alloys for lead-in wires and other uses in radio tubes or similar service gives freedom from gases in the interior of the metal which slowly emerge during the service of the vacuum tube with harmful results.

He has also reported[6] on vacuum melted and cast Ni-Cr and complex nickel alloys. In a personal communication he has stated that the advantage of vacuum melting for such alloys is due to the freedom from oxide inclusions and to the fact that they are practically carbon-free (under 0.02% C).

Only time can tell whether such precautions as vacuum melting and vacuum pouring will pay for themselves in the production of special alloys for special purposes. The cost appears high since Rohn estimates it as "twice the cost of making crucible steel," though he does not indicate that he has applied the process to steel. However, in Rohn's practice he starts with a cold furnace and applies vacuum throughout the whole melting process, finishing by pouring in vacuum and, it would appear from the curves, allowing the ingot to freeze in vacuum, a complete cycle requiring 14 to 15 hours.

If vacuum melting were applied to steel melting only during the finishing of the heat, to eliminate CO and consequently FeO, without vacuum pouring, it should be neither a difficult nor a costly process. If it proved to be of value on a small laboratory scale, its application to commercial practice should introduce no insurmountable difficulties.

What is needed at present is a series of pilot tests on a laboratory scale. Half a dozen research laboratories of the steel industry are equipped to make the tests without much difficulty. Such tests would have a very good chance of bringing out fundamental information that would certainly be of the greatest interest and, more than possibly, of the greatest value.

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[2] T. D. Yensen, "Pure Iron and Allotropic Modifications," Am. Inst. Min. & Met. Eng., *Tech. Pub.* **185** (1929).

[3] N. A. Zeigler, "Gases Extracted from Iron Carbon Alloys by Vacuum Melting," Am. Inst. Min. & Met. Eng., *Ibid.*, **168** (1929).

[4] W. Rohn, "Technische Eigenschaften vakuumgeschmolzener metalle," *Zeit. für Metallkünde*, **21**, 12 (1929).

[5] W. Rohn, "Wassergekühlte Kupperkokillen," *Zeit. für Metallkünde*, **19**, 473 (1927).

[6] W. Rohn, "Vergleichende Untersuchungen über die Oxydation von Chromnickellegierungen bei hohen Temperaturen," *Elektrotech. Zeit.*, **1927**, 227, 317; "Säurefeste Legierungen mit Nickel als Basis," *Zeit. f. Metallkünde*, **18**, 387 (1926).

The board of the Blaw-Knox Company announces the recent acquisition of controlling interests in the Union Steel Casting Company, the Lewis Foundry and Machine Company and the National Alloy Steel Company. All concerns are in the Pittsburgh industrial district and manufacture iron and steel products.

In order to handle the increase in business and provide more suitable quarters, the Central Iron & Steel Company of Harrisburg, Pa., has recently announced changes in the location of its New York and Pittsburgh offices.

The New York district office, formerly in Suite 1506, 1507 Evening Post Building, is now located in Suite 516 in the new Cunard Building at 25 Broadway.

The Pittsburgh district office has been removed from 1606 Commonwealth Building to more suitable quarters at 1721 Oliver Building.

Calendar of Meetings

American Welding Society, National Fall Meeting, Cleveland, Ohio, September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, Ohio, September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Institute of Metals Division, National Fall Meeting, Cleveland, Ohio, September 9 to 12.

American Society for Steel Treating, Eleventh Annual Convention & National Metal Exposition, Public Auditorium, Cleveland, Ohio, September 9 to 13.

American Chemical Society, 78th Meeting, Minneapolis, Minn., September 9 to 13.

American Society of Mechanical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, Ohio, September 11 to 13.

American Electrochemical Society, Pittsburgh, Pa., September 19 to 21.

Technical Association of the Pulp & Paper Industry, Richmond, Va., and Washington, D. C., September 24 to 27.

Abstracts of Current Metallurgical Literature

In this section, there will each month appear brief abstracts of articles in the metallurgical field appearing in various publications. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible. In the very near future the abstracts will be arranged according to subject.

Der Einfluss des Zinns auf die Beschaffenheit, vor Allem die Walzbarkeit von Siemens-Martin-Flusstahl. W. Keller. *Stahl und Eisen*, Jan. 31, 1929, pages 138–139.

Chemical determination of low contents of tin. Current tests during operation of sheets with 0.25 to 0.99% tin and various carbon contents. Observation of occurring rolling-cracks. Cold-bending test, testing for forgeability, weldability, tensile strength and elongation.

Ein Beitrag zur Kenntnis der Ehnschen Zementations Probe. R. Wasmuht and P. Oberhoffer. *Stahl und Eisen*, Jan. 17, 1929, pages 74–77.

This paper discusses the application of the cementation test for testing and distinguishing good and poor steels in continuous operation; influence of the method of deoxidation on the result of the test. Occurrences at de-carbonization are considered.

Die Rekristallisation beim Warmwalzen. W. Tafel, H. Hanemann and A. Schneider. *Stahl und Eisen*, Jan. 3, 1929, pages 7–12.

Experiments in the re-crystallization of soft steel after rolling with different drafts from 650 to 1200° C. Experiments for finding the most suitable points to measure the grain-size, the influence of the original grain-size and the difference of grain-size in transverse and longitudinal section. Development of a space diagram. Discussion of results. Conclusions are given for practical operation.

Ueber die Transkristallisation des Aluminiums. E. Scheil. *Zeitschrift für Metallkunde*, April, 1929, pages 121–124.

Paper read at the general convention of the Deutsche Gesellschaft für Metallkunde, Dortmund, 1928. Dependence of structure formation on conditions at casting as, for instance, casting temperature, mold temperature and wall thickness of mold, are discussed.

Der Einfluss von Oberflächenbeschädigungen auf die Biegungsschwingungsfestigkeit. W. Zander. *Metallwirtschaft*, Jan. 11, 1929, pages 29–32; Jan. 18, 1929, pages 53–57; Jan. 25, 1929, pages 77–80.

It has often been observed that permanent fractures had their origin in small defects of the material, changes of section, and injuries to surfaces of engine parts (A. Foeppl, Vorlesungen, 10th edition, Vol. III, p. 63; Taubert, Maschinenbau (1923), p. 261). While in the ordinary tensile test only very brittle materials are influenced by small injuries to the surface the fatigue test shows also a considerable influence in tough materials which in practice are used especially as constructional parts for alternating stresses. Particularly in cases where engine parts have to withstand alternating bending stresses even extraordinary small surface defects caused a considerable reduction of strength values. The present investigation was made to show in how far such defects on the surface of the material, which often can hardly be avoided in the usual course of machining, cause a reduction in durability. Further it was to be determined how much the durability is reduced by exactly determined defects. For this purpose, artificial surface injuries were produced mechanically in different ways on sample rods and their influence on the result of the fatigue test with alternating bending stresses thoroughly tested.

The Influence of Pickling Operations on the Properties of Steel. H. Sutton. *Iron & Coal Trades Review*, June 21, 1929, page 941.

Further discussion of paper at Sheffield meeting of Iron & Steel Institute. Cf. *Ibid.*, May 3, 1929, pages 674–6; May 24, 1929, page 796. Overstrain resulting from the quenching operation may be one of the causes of failure during pickling. Fully hardened carbon steels are apt to crack during pickling. W. H. B.

Brittleness in Mild Steel. C. R. Bolsover. *Iron & Coal Trades Review*, June 21, 1929, page 941.

Further discussion of paper at Sheffield meeting of Iron & Steel Institute. Cf. *Ibid.*, May 3, 1929, pages 665–7; May 31, 1929, page 823. W. H. B.

The Oxidation of Iron and Steel at High Temperatures. L. B. Pfeil. *Iron & Coal Trades Review*, June 21, 1929, page 941.

Further discussion of paper at Sheffield meeting of Iron & Steel Institute. *Ibid.*, May 10, 1929, pages 717–8; May 17, 1929, pages 750–2. The iron-oxygen system apparently has no compounds. The solid solutions in this system split up on cooling and yield the Gamma-Zeta solution precipitating the Beta, on cooling, and possibly the remaining solid solution at a certain temperature could not split up into eutectoids. Nickel is curious in alloy steels in that it can only exist as metallic nickel in the scale, if the scale contains more than a certain amount of iron. W. H. B.

Untersuchungen an Wolfram-Magnetstahl. K. Brecht, R. Scherer and H. Hanemann. *Stahl und Eisen*, Jan. 10, 1929, pages 41–42.

Experiments to find the most favorable annealing and hardening temperature for good workability and best magnetic values. Unfavorable action of free carbides on the magnetic properties.

Zur Kenntnis des Systems Nickel-Eisen. G. J. Sizoo and C. Zwikker. *Zeitschrift für Metallkunde*, April, 1929, pages 125–126.

A simple and quick method to produce single-crystal wires of nickel and nickel-iron is given. The easy machinability of these crystals makes it possible to investigate, in pure samples, the electrical properties of nickel-iron alloys in relation to their composition. The specific electric conductivities and the resistance temperature-coefficients have been measured for a number of alloys.

A Proposed Nickel-Refining Process. Frank E. Lathe. *Canadian Chemistry & Metallurgy*, June, 1929, pages 174–176.

A paper read before the 12th Dominion Chemical Convention at Toronto, May, 1929. Present methods of nickel refining are reviewed and a new method described for the separation of nickel from copper and precious metals in nickel-copper matte. The insolubility of nickel sulphide in acids of moderate strength was overcome to a considerable extent by rapid cooling and granulation. Well granulated matte, ground through 80-mesh, and treated for 3 hours at 80–100° C. yielded a residue containing only 0.2% Ni. Very little copper went into solution at this time, but was immediately precipitated when the solution was passed over fresh matte, due to the liberation of hydrogen sulphide. The gold, silver and the platinum metals go entirely with the copper. This permitted a separation of about 99.8% of the nickel from 100% of the copper and precious metals. A commercial refining process for ordinary Sudbury mattes would work out about as follows: (1) Cessation of the converter blow with 2–3% of iron still in the matte, (2) granulation of the matte in water, (3) grinding to 80-mesh, (4) solution of 99–99.9% of the metal and iron in 30% sulphuric acid at 80–100° C., (5) partial oxidation (burning) of the liberated hydrogen sulphide, with separation and recovery of free sulphur, (6) removal of part of the solution in a cyclic process, for oxidation of iron and precipitation with nickel hydroxide, (7) crystallization of most of the nickel sulphate by cooling, (8) dehydration of the nickel sulphate at 300° C., (9) decomposition of the nickel sulphate at 800° C. with absorption of the sulphur trioxide in the molten liquor from (7), (10) reduction of the pure nickel oxide to metal with petroleum coke in a reverberatory furnace, (11) melting and converting of the residue of copper sulphide, (12) electrolysis of the copper with complete recovery of the precious metals in a very concentrated slime. The method offers in a single operation an almost quantitative separation of the nickel and copper in a condition of high purity for the recovery of a by-product of the sulphur originally in the matte, and for the recovery of precious metals in a very concentrated form. Costs of plant requirements would be moderate and operation costs low. W. H. B.

Ueber die Wirkung von Schutzanstrichen auf Aluminium-Legierungen. H. Rohrig. *Korrosion und Metallschutz*, April, 1929, pages 85–88.

Very exhaustive tests are described, made to determine the behavior of aluminum alloys protected with various kinds of paints if exposed to river water and to salt water spray, and to find the influence of metallic compounds in the paints. The samples consisted of sheets of hard Lautal, 1 mm. thick which were coated with paints especially recommended for protection of light metals by the manufacturer. The results show first that three coats give better protection than only two coats. Paints containing lead have a harmful influence especially under strongly corroding conditions. Litharge coating causes a peculiar destruction of the metal probably due to some electrolytic action between Al and Pb. All protective coats when deteriorating also cause a reduction in the tensile strength of the material, and, further, the bendability was also reduced. Paints containing aluminum powder were superior to most other kinds of paints. In general, metal-free coatings gave best results.

Das Neue Kupferwalzwerk im Kabelwerk der A E G. D. Bernhoeft. *Zeitschrift für Metallkunde*, April, 1929, pages 113–116.

The Cable-Works Oberspree play an important part in the consumption of the raw material of Germany. About one-sixth of the total consumption of copper is worked here. The plants have lately been enlarged by alterations and new buildings by using the most recent technical improvements in manufacture. The copper rolling mill described in the article can roll about 180,000 tons yearly with three-shift operations. From heating furnace to finishing mill, the plant works entirely automatically. As well, the transport of the finished wire to storage and in the pickling bath is automatic. From the pickling baths in which copper has accumulated the latter is recovered electrolytically.

New Type Furnace Changes Brass Melting Practice. *Brass World*, May, 1929, pages 108–109.

A radically new type of brass melting furnace embodies greatly improved efficiencies such as decreased fuel requirements, lower maintenance and labor costs, reduced metal loss, and higher quality and larger casting production. The furnace is a rotary gas retort type and was sponsored by the American Gas Associations and built by the American Gas Furnace Co., Elizabeth, N. J. The retort is externally fired and is enclosed in a shell heavily insulated and refractory-lined. The insulated sheet steel drum or shell is mounted on 2 bearings held by a steel frame permitting tilting at any desired angle. Ten gas burners, 5 on each side, are mounted on this drum, so that they fire into its interior. The special alloy metal retort inside revolves with a motor and variable chain and gear drive. Volatilization losses run about 5–6%. An installation at the plant of the Trenton Brass & Machine Co., Trenton, N. J. shows a fuel consumption of $2^1/_2$–4 cu. ft. of gas per lb. of brass melted. Other savings are in labor, faster heat transfer and fuel saving in retention of heat by retorts overnight. Working conditions are improved by absence of smoke, fume, noise and limitation of heat emission. W. H. B.

The Erosion of Guns. R. H. Greaves, H. H. Abram and S. H. Rees. *Iron & Coal Trades Review*, May 3, 1929, pages 648–654; May 17, 1929, page 754.

An abstract of a paper read before the Annual Meeting of the Iron & Steel Institute. It includes many photomicrographs, a discussion and a reply. Gun erosion is studied from the metallurgical aspect and is defined as the removal of metal from the bore of a gun by the action of the propellant gases. The bore of any gun which has fired smokeless propellants indicates two characteristics at the surface: (1) a very hard skin, and (2) a network of surface cracks a few hundredths of an inch in depth. The characteristics of these are noted. Guns in which various smokeless propellants were used were examined and the tests employed are described. Heat treatment is found to have little effect on metal erosion. With propellants of the same size, the loss of weight due to erosion falls off very regularly with the decrease in calorific value of the propellant and the consequent decrease of maximum temperature attained by the hot gases. The steels showed the same order of corrodibility under the action of different propellants. Chemical action has little influence on the progress of erosion by modern propellants. The erosion occurring in large guns is almost wholly due to the melting and sweeping away of metal from the bore surface by highly heated propellant gases. The metal removed depends: on the nature of the propellant, the calibre and ballistics of the gun and on the physical properties of the metal-melting point, specific heat, latent heat of fusion, thermal conductivity and characteristics of the metal surface affecting the rate of transfer of heat from gas to metal. A high melting point is most essential in a gun steel. The use of a cooler propellant affords the only practicable method of reducing erosion. W. H. B.

Dauerversuche mit Metallen. P. Ludwic and R. Scheu. *Metallwirtschaft*, Jan. 4, 1929, pages 1–5.

Report of the Technischen Versuchsanstalt der Technischen Hochschule Wien. The phenomenon of fatigue in metals has been thoroughly investigated by testing 20 different materials comprising Duralumin, Elektron, electrolytic copper, bronze, several kinds of steel and cast iron. The tests to determine in which way continuous tests could be replaced by short-time tests. Preparation of samples and manner of tests are described in detail and results given in diagrams and charts.

Ueber den Einfluss von SO_2 auf Bronze und Kupfer. R. Röntgen and G. Schwietzke. *Zeitschrift für Metallkunde*, April, 1929, pages 117–120.

The article takes up the influence of SO_2 as a cause for gas porosity. Comparative results on bronze and copper are given.

Röntgenographische Untersuchung des Aluminiums Bei Hohen Temperaturen. A. J. Alichanow. *Zeitschrift für Metallkunde*, April, 1929, page 127.

Aluminum has been examined by X-ray to determine whether it shows an allotrophic transformation at temperatures between 575 and 600° C. It was proved that its structure remains unchanged, namely, the structure of a cube with centered faces. So far, the same linear system had always been observed independent of previous treatment; however, at higher temperatures no measurements had been carried out.

Third Report on the Heterogeneity of Steel Ingots. A Committee of the Iron & Steel Institute. *Iron & Coal Trades Review*, May 3, 1929, pages 640–644.

An abridged report consisting of 5 sections: (I) Introduction; (II) The Liquidus and Solidus Ranges of Some Commercial Steels, by J. H. Andrew and David Binnie; (III) The Solubility of Iron and Manganese Sulphides in Steel, J. H. Andrew and David Binnie; (IV) Interim Report on the Density of Molten Steel, C. H. Desch and B. S. Smith; and (V) The Effect of Latent Heat on the Solidification of Steel Ingots, N. M. H. Lightfoot. Several charts and photomicrographs are included. W. H. B.

New Metal Compound for Wire Drawing Dies. Dr. James Silberstein. *Brass World*, May, 1929, page 111.

A new metal substance with tungsten carbide as one of the main constituents has been developed in Germany which is being successfully used in the drawing of any kind of metal wire, alloy wire and steel wire. The wire produced is of uniform size, and round. One and one-half million lbs. and more wire has been drawn in a single die. Production capacity has been increased at least 20% and the quality of the wire is improved. W. H. B.

British Society Holds Conference on Chromium. *Brass World*, May, 1929, pages 105–107.

An abstract and discussion of a paper by G. E. Gardam. The concentration of sulphuric acid and its relationship to the chromic acid content are important. For every 100 parts of chromic acid, 1 part by weight of sulphuric acid is used. A typical bath contains chromic acid (CrO_3) 250 g./1 (40 oz. per Imperial gal.), sulphuric acid 2.5 g./1. (0.4 oz. per Imperial gal.). The pressure of trivalent chromium is probably essential for good depositing and its content may reach 2%. Trivalent chromium should be limited. The current density is usually 100–300 amp. per sq. ft., and the surface of the cathode is formed of a metal of high hydrogen overvoltage (such as copper). Attention is given on the influence of the cathode metal, anodes, properties and applications of electrodeposited chromium. L. Wright in discussion stated that a matte deposit had been obtained on both laboratory and commercial scale and they could be highly polished subsequently. These deposits were obtained from a bath having a chromic dichromate content. He claims the working range of a bath is determined by the ratio of chromium to hydrogen rather than chromic acid to sulphuric acid. W. H. B.

Microstructure of Rapidly Cooled Steel. J. M. Robertson. *Iron & Coal Trades Review*, May 24, 1929, pages 790–792; May 31, 1929, pages 829–830.

A brief discussion of theories of heat treatment of steel and the establishment of a modified theory regarding the connections between the rate of cooling and the temperature of the transition. As the rate of cooling is progressively increased, the temperature at which the transformation begins is gradually lowered. When a certain rate of cooling is attained, there is a sudden discontinuous lowering of the change to the neighborhood of 300° C. This rate is known as the "critical rate of cooling." A new conception of relation between transition constituents and normal changes is discussed and an investigation made of the microstructure obtained by different methods of cooling including cooling in molten lead. Seven groups of microstructure are formed and characteristics of each noted. Many illustrations are shown. W. H. B.

Mechanical and Metallurgical Properties of Spring Steels as Revealed by Laboratory Tests. G. A. Hankins and Miss G. W. Ford. *Iron & Coal Trades Review,* May 3, 1929, pages 657–761.

Results are given on low-chromium steel, high-chromium steel, a nickel-chrome steel and two water-quenched carbon steels—one 0.6% C, as used in tests previously reported (Journal of the Iron & Steel Institute 1926, No. II, page 265). Endurance fatigue limits have been determined on each steel in 3–4 conditions of heat treatment. Results are tabulated of: fatigue, impact, tensile and torsion tests, also comparisons of mechanical properties of hardened and tempered spring steels and of torsion test results. Results of these and of the early tests are discussed together: on the endurance basis, indications of the Izod test, and surface conditions and fatigue. W. H. B.

The Influence of Pickling Operations on the Properties of Steel. H. Sutton. *Iron & Coal Trades Review,* May 3, 1929, pages 674–676.

An experimental study of the influence of pickling in acid solutions of several kinds of steel strip leads to the following conclusions: (1) In general steel is embrittled by pickling in sulphuric acid and other acid solutions, the degree of brittleness depending on the composition and condition of the steel as well as upon the pickling conditions; (2) in general, the brittleness of a particular steel is greatest when the steel is hardest and least when softest; (3) immersion in boiling water for 30 min. substantially removes the brittleness due to pickling—an effect obtained by storage of some length. W. H. B.

Metallanalyse mit Elektronenwellen. E. Rupp. *Metallwirtschaft,* May 10, 1929, pages 446–448.

A short review on the methods of investigating the crystal structure of a metal. The new views on the corpuscular and quanta properties of light as applied also to electron waves permit a very simple and photographically instructive analysis of the structure. The method is briefly described.

Ueber Kokillenguss. Hermann Obermüller. *Zeitschrift des Vereines deutscher Ingenieure,* May 4, 1929, pages 613–617.

The different procedures of casting in permanent molds are explained and sand casting, die casting and ingot mould casting compared. The most important features of the method, as shape of ingot mould (material, gates, pouring heads, venting, inclination of walls, cores) and the casting proper are described. In conclusion, the economy of the process is briefly discussed.

Das Röntgenlaboratorium an der Technischen Hochschule Stuttgart. Dr. Glocker. *Zeitschrift des Vereines deutscher Ingenieure,* May 11, 1929, pages 637–638.

The equipment of the institute and especially the safety arrangements for protection against effects of the X-ray are described in detail. Most of the work done deals with application of X-rays for the testing of materials, but the whole field of physico-technical applications and also the medical use of the rays is treated, protective arrangements are investigated and measuring methods carried out and developed.

Untersuchungen über den Einfluss der Walztemperatur auf die Eigenschaften der Schienen. R. Stumper. *Stahl und Eisen,* Feb. 7, 1929, pages 177–187.

Discussion included. Report No. 138 of the Werkstoffauschuss of the Verein Deutscher Eisenhüttenleute. Means so far taken to improve the quality of steel for rails. Structure of ordinary rail steel. Grain and mesh-structure and its influence on the qualities of the material. Methods to obtain a finer grain. Experiments on the influence of rolling temperature on the qualities of rails. Determination of strength, hardness and notch-toughness in head, web and foot after different finishing temperatures. Notch-impact-tests between—10 and 200° C.

Beiträge zu den Systemen Eisen-Silizium, Eisen-Chrom und Eisen-Phosphor. P. Oberhoffer and C. Kreutzer. *Stahl und Eisen,* Feb. 7, 1929, pp. 189–190.

This investigation had the aim to clear up the question when and how the transformation from α- to γ-iron and from γ- to δ-iron takes place in Fe-Si and Fe-Cr systems. The methods and apparatus used and the precautions taken in guarding against wrong conclusions are described in detail. The X-ray tests show that with more than 2.5% Si an immediate transformation from α- to δ-iron takes place while with less than 2.2% Si the alloys show γ-mixed crystals. The experiments with Cr-Fe alloys show definitely that over the active range from 0 to 100% Cr no chemical compound is formed. Above 14.77% Cr no γ-transformation takes place. Fe-P alloys with from 0.16 to 23.89% P show up to 1.11% P the α-type of pure iron. From 2.28% P and more Fe 3P is formed, and at 21.27% a further compound Fe2P was found. With still higher amounts of P the spectrogram showed new lines, the character of which could not be determined.

Nickellegiertes Gusseisen. H. Unger. *Giesserei Zeitung,* April 1, 1929, pages 181–188.

The author reports on and discusses the results of tests made by the International Nickel Company with cast alloyed with nickel. The most conspicuous feature of the addition of nickel to cast iron consists in the finer grain and therefore greater uniformity of structure at different wall thicknesses; combined herewith is a reduction of sensitiveness against quenching. Similar to Si, the addition of Ni favors the formation of graphite and the disintegration of carbide. Due to the greater homogeneity of the structure the addition of nickel also influences the physical properties favorably and lessens the tendency to forming porous castings. The tensile and bending strength was usually increased. Numerous examples of practical cases show that the nickel alloyed cast iron is throughout of better quality and possesses better wearing properties. It should be always used where great density of material, fine grain, uniform hardness, toughness and resistivity against corrosion and temperature are required.

Oxidation of Iron and Steel at High Temperatures. L. B. Pfeil. *Iron & Coal Trades Review,* May 10, 1929, pages 717–718; May 17, 1929, pages 750–752.

Includes a brief discussion. From a paper read before the Annual Meeting of the Iron & Steel Institute in London, May 2–3, 1929. A study is made from the standpoint of the mechanism of oxidation of iron and steel rather than the rate of oxidation in a quantitative sense. When iron and steel are heated at a red heat in air, the scale forms as a series of layers possessing different appearance, properties and chemical composition. This formation is independent of the kind of iron or steel. Normally 3 layers are formed: about 10% is outside layer (1), about 50% middle layer (2), and the remainder, the innermost layer (3) in contact with the unoxidized metal core. The appearance of the scale layers and factors determining it are discussed. Apparently oxygen penetrates to the core with iron oxide acting as a "carrier." Probably there is a continuous series of solid solutions over the major portion of the iron-oxygen system with a gradually decreasing dissociation pressure on passing from the higher to the lower oxygen content. It matters little whether the iron dissolves and diffuses outward as atoms of iron or as molecules of FeO, the essential feature being that iron leaves the core without forcing outward the already formed scale. Experiments indicate the existence of a continuous series of solid solutions from 72% Fe and 28% O_2 to FeO (77.73% Fe and 22.2% O_2). The upper limit of the two-phase area is at 72% Fe which is equivalent to 73.5% Fe_2O_3 and 26.5% FeO. Whereas increased concentration in scale may be possible by direct solution of iron, experiments show that increase can occur without direct solution of iron in the scale. The outside layer with content of 71.04–71.86% Fe increases in thickness as the oxidation is continued, and when oxidizing conditions are severe, and disappears entirely when the atmosphere is weakly oxidizing. The inner surface of the middle layer corresponds in position and in surface characteristics with the surface of the unoxidized iron, regardless of conditions of oxidation. Surface characteristics, envelopment of foreign particles by progressive oxidation, and results in the cases of alloy steels, nickel-iron alloy, chromium alloys, manganese and silicon-steel alloys are briefly touched upon. The irregular distribution of the alloying elements can only be explained by supposing that the iron is removed from the zone of active oxidation and deposited free from other elements or the outside surface of the specimen. The structure of the scale varies very much with the rate of oxidation, with time of oxidation and with the temperature. Tables indicate: the oxidation of decarbonized steel sheet at 930° C. in a controlled air stream, the effect of temperature on critical rate of oxidation and the effect of rate of oxidation on composition of crystalline scale layers at a temperature of 930° C. Only the first film of scale forms as pseudomorph of the ferrite, further oxidation resulting in an irregular growth in crystal size. An explanation of the mechanism of the oxidation of iron and steel must deal satisfactorily with the four following points: (1) the scale is normally smooth, compact and free from cracks and fissures in spite of the oxidation involving an expansion of the order of 100%, (2) the scale consists normally of 3 very distincts layers, differing in appearance, structure and composition. With a few exceptions, iron-ferrous elements present in iron before the oxidation are concentrated in the innermost of the 3 layers of scale, (3) foreign substances placed on the surface of the iron are not forced away by the formation of the scale, but remain unmoved and become completely enveloped by the scale, (4) when oxidation is slow the formation of large scale crystals exhibiting plain crystal faces occurs, the scale surface sometimes shows high relief. The outer part of the scale is the last to form, the middle forming first. W. H. B.

Ueber die Temperaturabhängigkeit des Fliessens im Gebiete Elastischer Nachwirkung. R. Becker and W. Boas. *Metallwirtschaft,* April 5, 1929, pages 317–321.

The lattice theory has been a failure in cases which are connected with permanent deformations. An attempt is made to explain this by structural and thermal unhomogeneities. Flow-velocity is caused by thermal variations. The latter are measured on spirals of copper wire in the range of the elastic after-effects. The characteristic variation-energy is determined from the relation of the measured temperature.

Güteverbesserung der Gusswaren. A. F. Hager. *Giesserei Zeitung,* May 1, 1929, pages 251–253.

This paper discusses the ways and means to improve the quality of gray iron and make it equivalent to steel. Additions of Cr, Ti or Va did not have the desired result; steel and ferro-silicon gave satisfactory results if uniform mixing would be obtained. The ratio of coke to metal, influence of air velocity, manner of charging in cupola-furnaces, pre-heating are thoroughly treated. In conclusion, the author also considers castings of some special bronzes.

Ueber das Gussgefüge von Kupfer. P. Siebe. *Metallwirtschaft,* April 26, 1929, pages 391–395.

The methods of metallurgical testing are discussed. The casting-structure of copper and its importance for the latter working. Change of casting-structure during refining in the furnace and at different conditions during casting.

Brittleness in Mild Steel. G. R. Bolsover. *Iron & Coal Trades Review,* May 3, 1929, pages 665–667; Discussion, May 31, 1929, page 823.

Abstracts of a paper read before Iron & Steel Institute. Under proper conditions of forming and subsequent heating, brittleness in articles produced from dead-soft steel of satisfactory quality can be produced in all qualities of soft steel. It appears to be due to the imposition of tensile stresses on a portion previously subjected to compression or that the effect is a fundamental property of cold-worked material. Dead-soft steel, free-cutting steel and Armco iron all showed distinctly the harmful effect of combined cold-work and subsequent reheating on the brittleness, of the steel. Summarizing: (1) mild steel becomes brittle if deformed beyond certain limits and reheated to 250° C., while the undeformed portions of the same steel remain perfectly ductile, (2) if cold-worked and reheated as above impact values are lowered from 90 ft.-lbs. to less than 10 ft.-lbs. when tested at room temperature, (3) impact resistance increases with a rise of testing temperature until at 80° C. the reduction is only such as would be expected in view of the increased hardness induced by cold-working, (4) for different conditions of the steel, the temperature at which the induced brittleness is lost varies, (5) normalized steel which has been subsequently worked and reheated becomes brittle at a higher testing temperature than that which has been worked only (at a higher temperature than the normalized material), (6) increasing phosphorus contents increase the loss in ductility, particularly in steels reheated after cold-working, (7) apart from their influence on the question of impact testing, the results given are of vital interest in connection with pressed articles—particularly if reheated after pressing in view of the increasing use of such articles for vital parts as lifting chains. An abridged account of the discussion brought out that the steel experimented with contained 0.14% C and 0.6% Mn whereas grain-growth is more liable to take place in steels containing 0.05–0.13% C and 0.35–0.4% Mn. More pronounced results might be expected from the latter class of steels. Emphasis was also put on the effect of phosphorus with regard to brittleness. It is necessary to determine whether the brittleness is of a transitory type or whether permanent. W. H. B.

Die Ausbesserung von Aluminium-Gussteilen durch Schmelzschweissverfahren. H. Reininger. *Giesserei-Zeitung,* March 1, 1929, pages 125–131.

A distinction is made between parts which can be repaired by welding and such parts which must be scrapped. The parts to be welded must be cleaned mechanically of the adhering dirt, the places where welding is to be done are then cut properly for taking up the molten material; these places must first be treated with NaOH. After this, pieces to be welded, are heated. The usually used weldable aluminum alloys for casting are discussed and methods for repairing by melting-welding are indicated. Electrical methods as well as kneading-welding methods are not used for repairing cast alloys. Oxy-acetylene methods must be used with certain precautions. The cooling must be done very slowly, especially with complicated shapes; proper methods are given. After-treatment of the welded spots is not usual. An index of literature concludes the paper which also contains numerous micro-photographs of textures of welded parts.

New Method for the Production of Sound Steel. Charles Parsons and H. M. Duncan. *Iron & Coal Trades Review,* May 3, 1929, pages 654–655; Discussion, May 17, 1929, pages 758–760. Abridged.

The author's method of overcoming segregation and axial unsoundness is based on the principle that the freezing of the ingot should proceed from the bottom upward, the isothermals being substantially parallel to the bottom of the ingot. Steel ingots were cast by pouring the molten metal into a mould with its longitudinal dimensions greater than its vertical. Thick refractory materials cover the sides of the mould and a bottom chill of large dimensions (preferably of metal) preheat the mould to a high temperature before the metal is poured therein. It further supplies heat continuously to the upper surface of the molten metal after casting. Chemical analysis must be considered jointly with sulphur prints and micrographs in determining the heterogeneity of the ingot. Segregation increases with the size of the ingot. Discussion brought out the following points: heating of the walls cannot prevent the effect of differential freezing, the shape of the ingot does not conform with practical experience. There are 4 principal defects in steel ingots: (1) axial weakness, (2) axial segregates, (3) inverted type of cone segregate laying midway between the center and the outside and (4) iron-metallic inclusions. Micro-examination of specimens from one of the ingots showed marked segregation, particularly in the case of carbon. Two kinds of stresses are recognized; sheer and bulk, the former depending upon temperature gradient of the metal as it sets. When a long ingot is cooled in horizontal layers no bulk stresses are produced. Filling the mould with nitrogen might decrease considerably the amount of crust formed. W. H. B.

Zur Theorie des Gusseisens. *Giesserei-Zeitung,* March 1, 1929, pages 137–140.

The various possible forms of carbide and graphite are explained on the usual iron-iron carbide-diagram; it is shown under which conditions carbide and graphite are permanent. The different stages are discussed in detail and a theory is developed based on the actual constitution of cast iron; this theory is in agreement with practical observation. The chemical constitution is considered as the one determining the formation of the structure provided that no other element besides carbide and graphite is predominant.

Ueber Lagerbronzen. Edmund R. Thews. *Giesserei-Zeitung,* Feb. 15, 1929, pages 97–103.

This paper compares cast iron bearings and pure copper-tin bronzes. It considers the influence of small amounts of other elements, the influence of larger amounts of zinc, lead and phosphorus on the mechanical qualities of bearing bronzes. Special constituents of bronze-bearing metals are given.

Ueber die Löslichkeit und Diffusion von Wasserstoff in Metallen. G. Borelius. *Metallwirtschaft,* Feb. 1, 1929, pages 105–108.

Very many metals can occlude hydrogen, the author examines the laws of solubility of gaseous hydrogen in metals for low concentrations and checks the results with those obtained by previous investigators. He discusses the non-permanent metallic hydrides and the diffusion of hydrogen in metals, and also the occlusion of hydrogen in electrolysis.

An Investigation of the Physical Properties of Certain Chromium–Aluminum Steels. Frank B. Lounsberry and Walter R. Breeler. *Transactions American Society for Steel Treating,* May, 1929, pages 733–766.

Includes discussion. The following report pertains to a general investigation of the physical properties of steels, containing as main alloying constituents, aluminum from about 2 to 6 percent and chromium from about 7 to 13 percent, with silicon and carbon varying up to approximately 1 percent maximum. Data are also included on the effect of adding small amounts of additional alloying elements, such as nickel, cobalt, molybdenum, vanadium, manganese, tungsten and copper. The physical properties investigated were, (1) effect of thermal treatment on hardness and microstructure, (2) resistance to oxidation at elevated temperatures, (3) resistance to atmospheric corrosion, (4) forgeability, (5) tensile strength at normal and elevated temperatures, (6) impact values. It was found that aluminum effectively stabilized the alpha iron phase and when in combination with chromium greatly increased the resistance of the metal to oxidation at elevated temperatures.

High Chromium Steels. Owen K. Parmiter. *Transactions American Society for Steel Treating,* May, 1929, pages 796–816.

A paper discussing in general the composition, heat treatment and properties of high chromium steels, including the various low carbon, stainless steel types and the several high carbon-chromium die types. Special consideration is given to the more recent development of super stainless steel. The effect of various chemicals and other corrosive substances upon stainless steel is given in detail.

Festigkeitsuntersuchungen an Aluminiumlegierungen im Vergleich zu Schwermetallen und Ihre Bedeutung für den Konstrukteur. J. DRONAUF. *Metallwirtschaft,* March 22, 1929, pages 277–280; March 29, 1929, pages 301–303; April 5, 1929, pages 321–323.

The article gives the results of tests on copper-aluminum alloys for fatigue, tensile strength, elongation in their relation to the composition of the material and the manner of manufacture. Numerous diagrams are given.

Prüfung von Seildrahten durch Zug und Biegeversuche. G. SACHS AND H. SIEGLERSCHMIDT. *Metallwirtschaft,* Feb. 8, 1929, pages 129–138.

By means of new devices alternating bending tests with small and large bending radius (bending-rolling tests) have been carried out on wires of steel and other metals. By comparing the bending numbers with the properties found for the strength, approximately agreeing relations were found for non-ferrous metals between bending number, strength and deformation capacity of the material. The test showed that carbon steels usually do not agree with the relations found for non-ferrous metals. Bending-rolling tests offer, therefore, an indication of the behavior of steel wires in service stresses which cannot be replaced by any other test.

Haarrisse auf der Oberfläche von Blechen. ERICH A. MATEJKA. *Archiv für Eisenhüttenwesen,* May, 1929, pages 681–705, abstracted in *Stahl und Eisen,* May 4, 1929, pages 643–645.

In order to determine the causes for the formation of hair-line cracks on plates, a number of preliminary and extensive investigations were made on the steel during its production and rolling. These tests are very completely described and the results are given in tables and photographs. The main cause for the formation of the cracks was determined as the large difference of the surface and internal temperatures of the stock. The importance of careful and uniform heating in the ingot and slab is pointed out. Care should also be taken to avoid excessive temperature difference between surface and core when transporting the stock to the rolls. It is also stated that an overstressing of the surface of the stock should be avoided by the choice of the proper relation of rolling pressure and temperatures.

Sauerstoff in Eisen und Stahl. II. P. OBERHOFFER, H. HOCHSTEIN AND W. HESSENBRUCH. *Archiv für Eisenhüttenwesen,* May, 1929, pages 725–738, abstracted in *Stahl und Eisen,* May 30, 1929, pages 799–800.

Includes discussion. Report No. 146 of the Werkstoffauschuss of the Verein deutscher Eisenhüttenleute. This paper investigates the effect of oxygen on the properties of alloy steel by comparing two series of steels, one melted as usual in the crucible and the other under strongly oxidizing conditions. The steels high in oxygen showed a coarser fracture structure, they had a tendency to intercrystalline structures and disordered arrangement of ferrite and pearlite. The coarser structure can be followed as far as the forging. In case-hardening the high oxygen steels showed less depth of penetration of the case-hardened zone and a small irregular core in the hyper-eutectoid zone. The vanadium steels showed an abnormal structure throughout. The hardness range of the low oxygen steels is larger than that of the high oxygen steels. The latter have a strong inclination to overheating. The decline in hardness takes place in a smaller temperature range with the high oxygen steels. The high-oxygen steels have a tendency to inclined fracture. Investigations of the influence of oxygen on the temper brittleness did not give comparable results.

Prevention of Corrosion by Electrodeposition. VI.—Nickel Plating as a Corrosion Preventative. S. WERNICK. *Industrial Chemist,* March, 1929, pages 106–110.

Nickel plating as a corrosion preventive is discussed with special reference to the elimination of porosity and pitting. A deposit of 0.01 inch minimum thickness is advocated. A compromise in the amount of boric acid in the plating bath is necessary for, whereas increasing amounts lead to deposits of inferior protective qualities, decreasing amounts give rise to increasing difficulty of buffering. Attention is drawn to the deleterious action of iron salts. Composite deposits with an underlay of copper, zinc or bismuth are considered, and it is shown that a coating of nickel, followed by copper and then again by nickel, is of superior protective value to a similar total thickness of coating of nickel alone. The checking of porosity by this means is attributed in part to the varying orientation of the crystals of copper and nickel. Pitting of the deposit is due to the formation of stationary hydrogen bubbles or streams of bubbles proceeding from definite points or defects in the cathode surface. M. B. R.

Methods of Silver Plating. F. C. MESLE. *Metal Industry,* March, 1929, pages 128–130.

A discussion of methods used in plating tableware included formulas for silver solutions for the different classes of work.
M. B. R.

The Application of Science to the Steel Industry—Section III. W. H. HATFIELD. *Transactions American Society Steel Treating,* May, 1929, pages 817–836.

This paper is the third section of the third Edward De Mille Campbell Memorial Lecture presented before the 10th annual Convention of the society, Oct. 8–12, 1928. The general subject of this section might be heating. Various forms of heating for particular purposes, such as forging, annealing, normalizing, hardening and tempering, are discussed in some detail. The effect of forging on structure and properties is described. Thermal conductivity as influenced by various factors and the specific heats of iron and steel are covered.

The Constitution of Steel and Cast Iron. Section II—Part VIII. F. T. SISCO. *Transactions American Society for Steel Treating,* May, 1929, pages 837–850.

This installment, the eighth of the present series, describes the tempering of hardened steel. Preliminary to an explanation of the theory of tempering, the object and the various operations connected with this phase of heat treatment are discussed, as well as the various temperatures used and the proper time for holding at the tempering temperature. The discussion of the theory of tempering included a description of the structural changes taking place in tempering and also the structural changes which occur when a high carbon steel is cooled at various rates followed by tempering. The effect of tempering upon the structure of a high carbon steel is illustrated by representative photomicrographs.

Soft X-rays from Crystal Faces. D. W. RICHARDSON AND U. ANDREWES. *Nature,* March 9, 1929, page 344.

Tests were made by measuring the photo-electric current generated by the soft X-rays when they fell on a nickel plate, dividing this by the primary thermionic current, and plotting the fraction so obtained against the exciting voltage, and looking for discontinuous changes of slope in the resulting curves. With X-rays generated by bombarding a graphite surface, cleaved along the 0001 plane, seventeen discontinuities were found between about 70 and 320 volts, each of which agreed with the value, or the mean of two values a few volts apart, previously found with carbon. Fifteen discontinuities present with carbon target were absent with the graphite target. There is no doubt that the number of discontinuities from a single crystal surface is smaller than from a poly-crystalline surface. The K level discontinuity is not one which disappears. W. C.

Change of Electrical Conductivity in Strong Magnetic Fields. II.—Analysis and Interpretation of Experimental Results. P. KAPITZA. *Proceedings Royal Society,* March, 1929, pages 342–372.

The departure from the linear law in low fields is caused by an internal disturbance equivalent to a magnetic field. This hypothesis permits the resolution of the resistance into two parts, an "ideal" and an "additional" resistance; the latter is independent of the temperature and is identical with residual resistance near absolute zero. It is suggested that super-conductivity is a general phenomenon, but is observed only in certain metals in consequence of the disappearance of the "additional" resistance at low temperature. There is apparently some relationship between the atomic number of the element and the constant peculiar to the linear range of the law of change of resistance. E. W. H. S.

Penetration of Hydrogen into Metal Cathodes and Its Effect upon the Tensile Properties of Metals and Their Resistance to Repeated Stresses; with a Note on the Effect of Non-Electrolytic Baths and Nickel Plating on These Properties. C. F. LEA. *Proceedings Royal Society,* March, 1929, pages 171–185.

Nascent hydrogen, liberated at a cathode, penetrates the crystal boundaries of mild steel, nickel and "rustless" steel, but does not affect their tensile strength, although the elongation of specimens of mild steel is much reduced. The change of resistance to impact and the effect on repeated stress are unimportant. The fracture on failure is that of quenched or tempered materials. Nickel plating reduces the range of repeated stress; this is apparently caused by cracks formed in the deposited nickel.
E. W. H. S.

Methods of Joining Aluminum and Its Alloys. II. A. EYLES. *Metal Industry,* March, 1929, pages 116–118.

Welding of aluminum is discussed and formulas for fluxes are given. M. B. R.

Barrel Burnishing of Metal Products. H. L. BEAVER. *Metal Industry,* February, 1929, pages 84–85; March, 1929, pages 124–125.

A practical study of barrel burnishing reveals that the three principal factors to be considered the most are rotation of the burnishing mass, the relative specific gravity of the burnishing mass to the size and shape of the articles to be burnished. Cones and "diagonals" will reach crevices not touched by spherical burnishing balls. M. B. R.

Die Kerbschlagprobe Entwicklung und Kritik. F. Fettweis. *Archiv für Eisenhüttenwesen,* April, 1929, pages 625–674; also abstracted in *Stahl und Eisen,* May 23, 1929, pages 75–76.

Bibliography of 700 references with a subject index. Report of the Werkstoffausschuss of the Verein deutscher Eisenhüttenleute. The introduction gives a brief history of the development of the notched impact test beginning with 1884. The report considers the notched impact test from three viewpoints: (1) as a bending test, (2) as a notch test and (3) as an impact test. After investigating the difference between the notched impact and the tensile test, the drop hammers, bending machines and accessories, their errors and calibration as well as the method of measuring the deformation, are discussed. The procedures with the deformation and at fracture are thoroughly investigated, special attention being called to the basic importance of the occurrence of two types of fracture with steel. A discussion of the influence of temperature and sample shape upon the impact work follows, with constant consideration of the two possible fracture types. The influence of the material make up, of structure, chemical composition, heat treatment, hot and cold working, aging and temper brittleness and in conjunction hereto the relation between the notch-toughness and the other physical properties are discussed. In conclusion the defects of the notch-impact test, which make themselves especially noticeable when it is used in testing, are pointed out.

Das Giessen von Stahl in Eine Wassergekühlte Kupferkokille. W. Oertel. *Stahl und Eisen,* May 9, 1929, pages 696–700.

Includes discussion. Report No. 145 of the Werkstoffausschuss of the Verein deutscher Eisenhüttenleute. The results of the investigation were as follows: The advantages, offered by pouring steel in water cooled, copper molds, first are economical. With the use of many molds for the pouring of large heats it would be possible to get along with a considerably smaller mold storage, as the ingots cool very quickly and can be pulled a few minutes after pouring, and the molds are immediately ready for a new cast without preparation. The molds do not wear, they last almost indefinitely. As the ingots can be teemed without a hot top and the pipe is very short, the discard is very small. The surface of the ingot is clean and smooth, so that the ingots rarely need to be turned. The ingot has a finely developed ingot structure and is without large slag particles and ingot segregations.

Der **Einfluss des Herstellungsverfahrens und der Glühatmosphäre auf das Randgefüge der Werkzeugstähle.** E. Zingg, P. Oberhoffer and E. Piwowarsky. *Stahl und Eisen,* May 16, 1929, pages 721–725; May 23, 1929, pages 762–768.

Report of the Metallurgical Department of the Technische Hochschule Aachen. The investigation was made to determine under what conditions in gas cementation, free iron carbide results. The production and effect of a protecting gas for the heat treatment of high carbon tool steel is given. The occurrences in the heat treatment in calcium chloride and barium chloride salts are noted. The methods are given for preventing decarburization, without possessing the disadvantages of the cyanide additions. It was determined that dissolved carbon can easily diffuse through the α-solid solution, and that the penetrability of the α-solid solution for carbon is closely related to the physical purity of the steel and thereby with its properties.

Die **Bearbeitbarkeit Verschiedener Baustähle des Kraftwagenbaues.** A. Wallichs and K. Krekeler. *Stahl und Eisen,* May 30, 1929, pages 793–799.

This paper first compares several steels generally used in American automobiles with the materials used in Germany and thereby determines that with the same physical properties the difference in workability is so small, that it lies within permissible limits. The diagrammatic representation of the values gives a control point for the workability of the steels considered in the tests. It was determined with all steel types, with alloyed and unalloyed heat treating and case hardening steels, that the permissible limits of analysis exerted no appreciable influence on the workability. The investigation showed that alloyed steels, in general, were harder to work. In the unalloyed steels the carbon content played an important role.

Dauerbiegeversuche mit Stählen. E. Houdremont and R. Mailander. *Stahl und Eisen,* June 6, 1929, pages 833–839.

The results of 170 series of tests on steels of different composition confirm the known relation between the alternating bending strength and the tensile strength, while the relation between alternating strength and tensile strength plus elastic limit is better represented by a formula here derived than the one derived by Stribeck. The results are investigated to determine the influence of the composition, of the structure and the heat treatment on the alternating strength. In conclusion some results are given on the influence of a cold working by drawing on the alternating strength and on the notch sensitivity of the steels with fatigue bending tests.

Ueber den Einfluss der Elemente auf den Polymorphismus des Eisens. Franz Wever. *Archiv für Eisenhüttenwesen,* May, 1929, pages 739–748; also abstracted in *Stahl und Eisen,* June 6, 1929, pages 839–840.

Includes discussion. A periodic relation was proved between the behavior of an element toward the polymorphic transformation of iron and its position in the periodic system. The opinion is expressed that the same relation also holds for the properties of the homogenous solid solution series. This paper is report No. 147 of the Werkstoffausschuss of the Verein deutscher Eisenhüttenleute.

Ueber Einkristalle aus Eisen. H. Gries and H. Esser. *Archiv für Eisenhüttenwesen,* May, 1929, pages 749–761.

Report of the Metallurgical Department of the Technische Hochschule Aachen. The recrystallization procedure in pure iron and the most favorable influences for the production of single iron crystals is investigated. In addition to the solubility rate of the accompanying elements, the final crystal size of the recrystallization annealings of the pure iron is of deciding influence for a favorable crystal growth with the fixing of the amount of deformation. With increasing final crystal size the amount of deformation called forth by the recrystallization below Ac_3 also increases. The duration of the anneal and the height of the annealing temperature are also influences. A number of single iron crystals were produced. The beginning of the recrystallization with many and single crystals depends upon the uniformity of the deformation (elongations or upsetting). The orientation of the crystals to direction of the deformation force exerts a noticeable influence on the beginning of recrystallization with single crystals. The degree of deformation to be expended is least with the deformation of a rhombic dodecahedron surface and highest with a cubic surface. With increasing oxygen content the crystal size increases. With critical deformation and subsequent annealing the crystal growth up to 10% deformation and annealing at 850, respectively, 880° is completely stopped, if the solubility limit for oxygen is exceeded. An oxygen content of about 0.05% is determined as the solubility limit. The methods for the determination of crystal orientation on single crystals were investigated. The simplest and the most accurate method for the purpose under consideration depend upon the pressure figure formation and the reflection appearances. Further the hardness of single and many crystals were investigated. This is least for the cubic surface. It is larger for the octahedron surface and highest for the rhombic dodecahedron surface. The difference in hardness of individual crystal surfaces remains the same even with subsequent deformation. Contrary to previous investigations with increasing oxygen content an influence on the hardness in increasing tendency was proved. With the observation of the change of the orientation of the iron single crystals by deformation, rotations were determined, with which in the final form one of the symmetrical axes lies perpendicular to the rod axis, if the material is formed by rolls. It was observed that the dodecahedron surface was favored.

Ueber das Martensitsystem. K. Gebhard, H. Hanemann and Schrader. *Archiv für Eisenhüttenwesen,* May, 1929, pages 763–771.

Thermal investigations confirm the heterogeneity of martensite and the existence of a second meta-stable system of iron-carbon alloys. The lines of the martensite system are determined. The physical properties and the constitutional diagram are in agreement with this system. The phases of the martensite system and their relations are determined. In the meta-stable martensite equilibrium up to about 0.1% C only ϵ-iron occurs. From 0.1 to 0.37% C martensite consists of ϵ-iron and Heynite, while with steels of 0.37 to 0.9% C the constituents of martensite are Heynite and Hardenite. Above 0.9% C the quenched steel contains Hardenite and Austenite. With incomplete equilibrium, hardened steels also have Austenite below 0.9% C and Heynite above 0.9% C.

Fortschritte in Metallurgie und Betrieb des Hochfrequenzofens. H. Neuhauss. *Stahl und Eisen,* May 9, 1929, pages 689–696.

Report No. 166 of the Stahlwerkausschuss of the Verein deutscher Eisenhüttenleute. Includes discussion. After a short consideration of the current consumption of various high frequency induction furnaces in comparison with electric arc furnaces the manufacture of a low carbon iron free from red-shortness, in the high frequency furnace is discussed. Additional possible applications, for example, in a duplex process with a high frequency furnace and a cupola, are described and from the results of various oxidization tests with which the oxidizing effect was still further increased by blowing air on the surface of the metal the advantage of the high frequency furnace for decarbonization is proved. Additional investigations show the possible application of the high frequency furnace for the production of steel castings, rust resisting chrome steel and other special steels.

Translations

Negotiations are now under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English the best articles at almost the same time as they appear abroad instead of three months to one year later.*

Hair Line Cracks on the Surface of Plates*

By Erich A. Mateyka

In order to successfully overcome the surface cracks on plates, the question, if this is a case of a material defect or a working defect, must first be answered. By means of preliminary tests, which included 134 heats and only confined to the steel works, it was proved that only few influences, which extend back to the production of the steel, show a relation to the defect. In spite of this the main investigation was carried out on the broadest basis and corresponded in its make-up to the manufacture of the plate stock. The main investigation was made up of single and mass tests, the mass tests consisted of about 10,000 plates corresponding to 380 heats.

The main investigation showed that the occurrence of the defect was favored by: a low manganese content of the bath before the tap, short melting time, high strength of the material, sluggishness of the steel in teeming, shallow location of the surface blow hole ring and with the ingot mold, too heavy wall thickness and too small a corner radius. The defect though could not be controlled by the steel works; this was only possible by the following influences of the hot working; the manner of heating the stock, the rolling temperature, the rolling pressure and within a certain limitation the cooling water of the rolls. The results of the metallographic examination were also important, as these pointed out that the cracks represented a violent tearing of the otherwise sound surface. (Fig. 1.) The oxygen determinations carried out showed no difference between the good and defective plates.

All these observations point to the fact that the defect is to be found in the working and not in the material itself. An investigation of the stress of the material on hot working clearly showed the influence of the temperature differences, between the surface and the inside of the stock, caused by radiation and conduction losses. The above considerations lead to the conclusion that with the more pronounced cooling of the ingot surface localized tears may occur, and made possible an explanation for the several observations which characterize the defect (Figs. 2 to 5). So, for example, it was determined that in most cases only one side of the plate had tears and the material of another steel plant of the Eisenwerk Witkowitz, in which the tests were carried out, showed the surface defect less often. The first observation is covered by the fact that that side of the slab, which lies on the hearth of the heating furnace, usually is colder, as an arrangement for turning is lacking; further, this surface on leaving the furnace cools still more, as it then lies on the cold roll table. The material of the second steel plant is rolled without heating in the pusher furnace and is heated in a furnace, in which the ingots are placed below; so that it is heated uniformly all through. The often observed cracking of the heavier plates bears a relation to the mentioned deficiency of

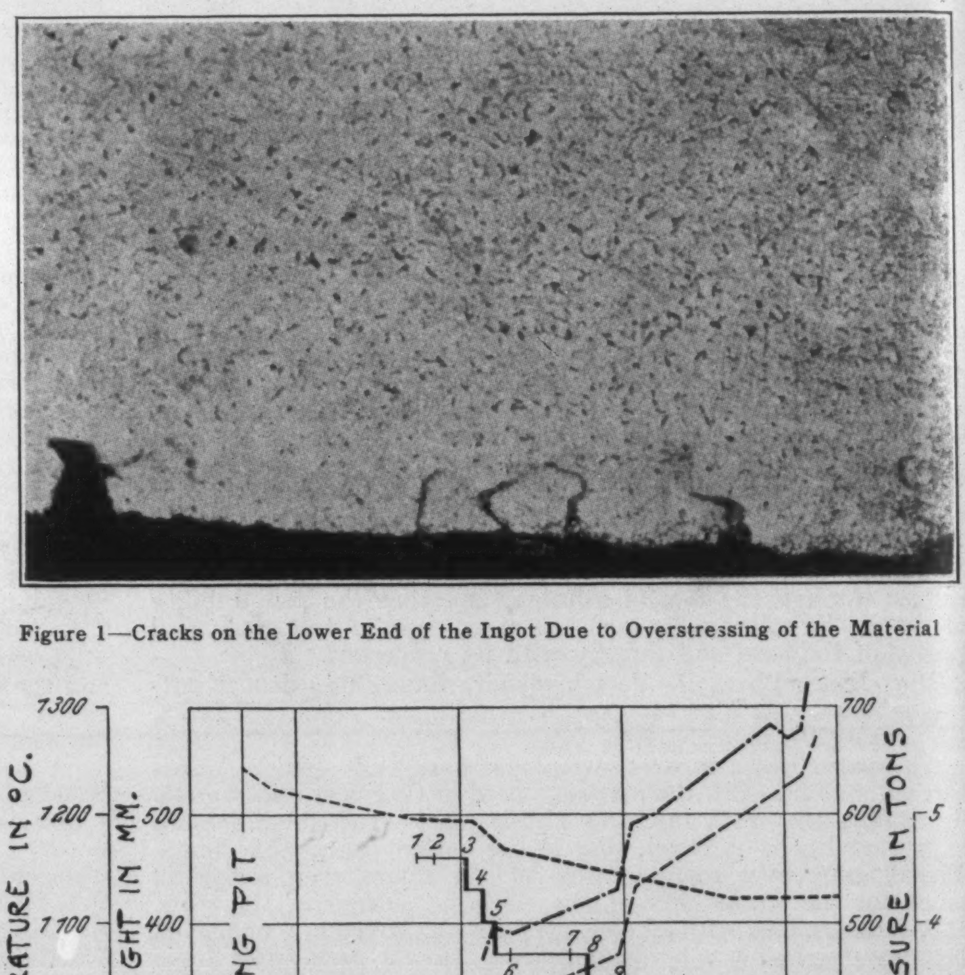

Figure 1—Cracks on the Lower End of the Ingot Due to Overstressing of the Material

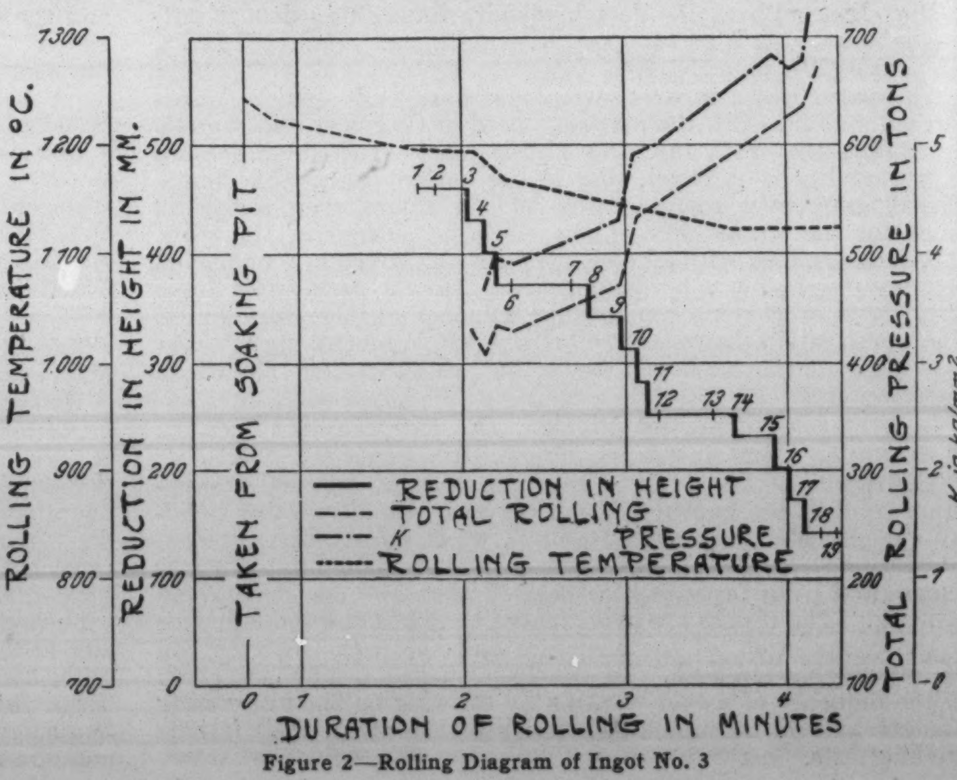

Figure 2—Rolling Diagram of Ingot No. 3

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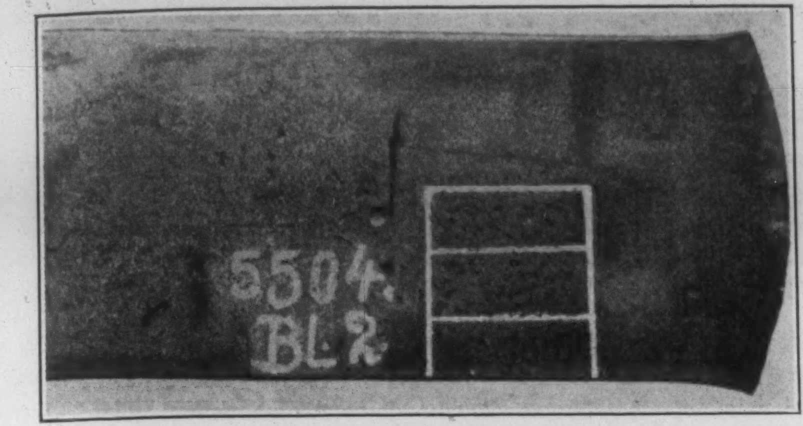
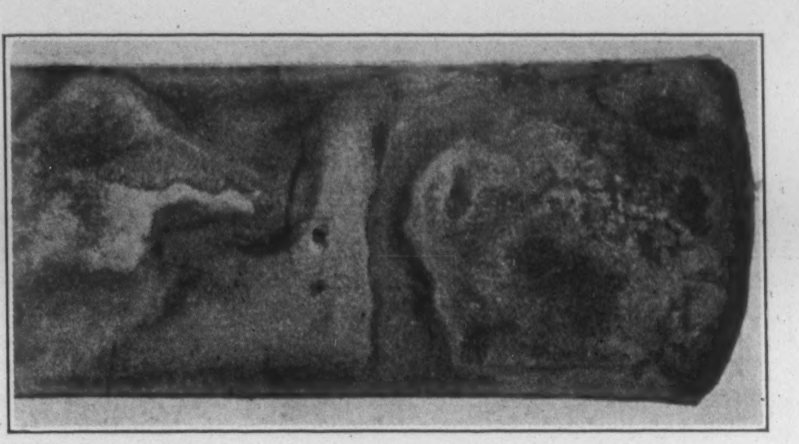
* Extract of a paper read before the Annual Meeting of the Verein deutscher Eisenhüttenleute on May 4, 1929. Translated from *Stahl und Eisen,* May 2, 1929, pages 643–645.





Lower side of the slab which lay on the roll table

Upper side of the slab which did not touch the roll table

Figure 3—Influence of Unequal Cooling on the Surface Crack Formation

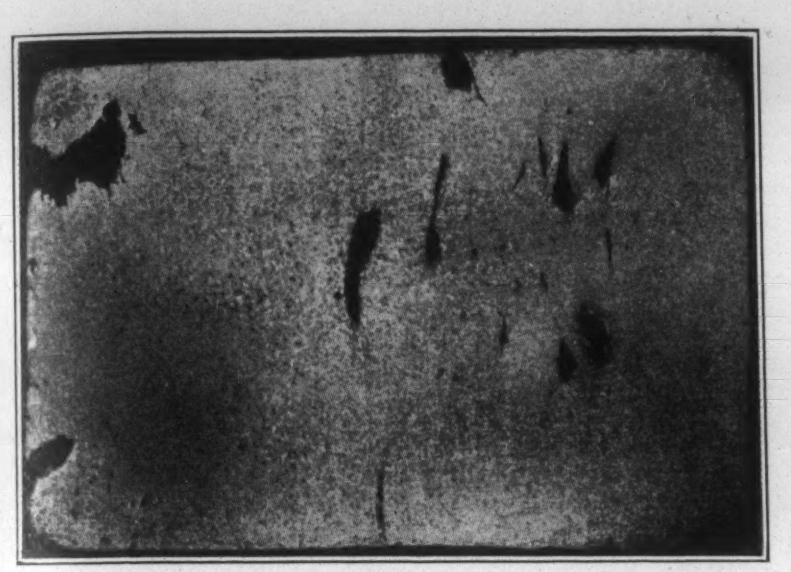


Figure 4—Position and Depth of Cracks Perpendicular to the Slab Surface

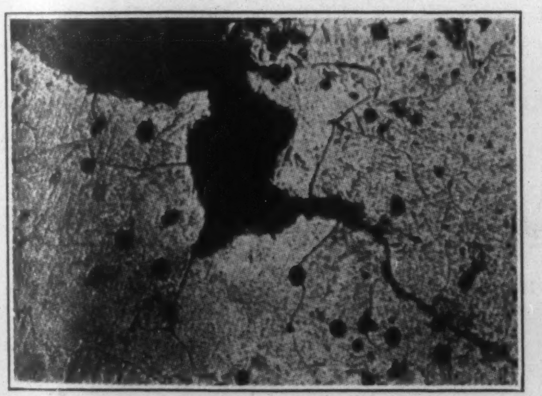


Figure 5

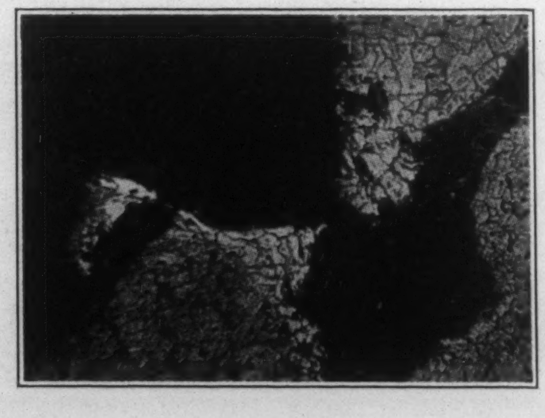


Figure 6

Enlargements of Cracks Shown in Figure 4

the pusher furnace in so far as the slabs for the heavier plates are not roughed down as far as for the lighter. Naturally with the given conditions and the controlled operation of the pusher furnace, there is the danger that the heavier slabs are not heated very uniformly, though the above-mentioned influences in the steel plant, which favor the occurrence of the defect on a basis of the principal tests, can be explained by the assumptions made. As can be seen from the literature these are throughout influences, which reduce the hot workability of the steel by an unfavorable influence on the development of the ingot structure. The surfaces of such ingots, which are weakened in the edge parts by the manufacture, will suffer surface damage and tear open earlier by the unfavorable stresses of the surface parts of an ingot by the perpendicular pressure effects in the rolling process.

In order to investigate how far the assumptions of the origin of surface tears on plates actually correspond to the facts, a series of tests were made. By the first test it was shown that in roughing with equal reductions in height the material is easily overstressed and surface tears occasioned, as due to the increase of the total rolling time the surface of the stock is cooled considerably, aside from the increased stresses with the progress of the rolling (Fig. 6). The second test confirms the results of the former in so far, as it shows, that the overstressing of the material, which may cause the formation of cracks, can be avoided by the proper choice of the reduction pressure. The third test confirms the correctness of the assumptions according to which the temperature differences in the stock may cause surface cracks. For these tests several heats were used, of which the one-half of the ingots were rolled according to the usual schedule, while the other half were left lying on the manipulator a few minutes before rolling out in order to increase the temperature differences between the surface and the core. (Fig. 7.) The first-mentioned ingots almost all had a clean surface, while the others showed surface cracks throughout. To complete this investigation another test was carried out, which furnished the proof, that also with long times of transporting the heated ingots or the roughly shaped slab from the furnace to the roll train promote the formation of surface cracks due to the surface cooling in that time (Fig. 8). The last test finally proved that lower rolling temperatures of themselves are not the cause of the defect, if the stock is heated uniformily throughout and rolled at the reductions in height corresponding to the lower temperatures.

Summing up it can be said: In order to prevent the formation of hair line cracks on the surface of plates, the ingot and also the slab must be heated with great care, assuming, of course, that in the steel plant, the steel has been carefully deoxidized, the proper ingot mold chosen and care taken to obtain a dense ingot on teeming with deep seated rim blow holes. A surface cooling of the stock, which has as a result a difference in temperature between the surface and the inside of the piece, should be avoided. By the correct choice of the relation of rolling pressure to rolling temperature a physical overstressing of the surface parts of the stock can be avoided.

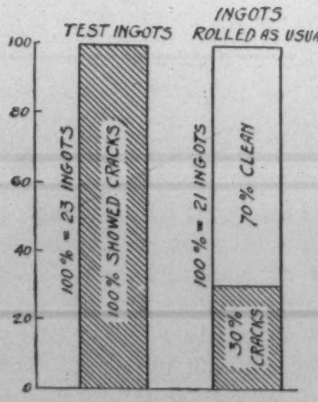


Figure 7

Influence of surface cooling on crack formation during cooling

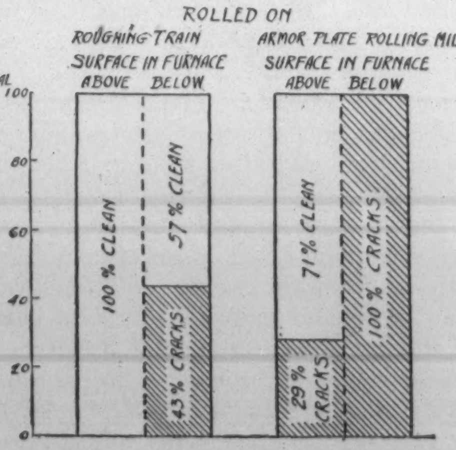


Figure 8

Influence of the transit time of the heat in the formation of surface cracks

Book Reviews

Die Bestimmung der Dauerfestigkeit der Knetbaren, Veredelbaren Leichtmetallegierungen. By R. Wagner. J. Springer, Berlin, Germany, 1928. 64 pages, 56 figs. Price, 6 R. M.

The fatigue of refinable aluminum alloys for structural parts has not been investigated very systematically up to the present in spite of the importance of this question for the construction of aeroplanes. For this reason, the present investigation merits considerable interest in which, besides several kinds of duraluminum, scleron and lautal, electron and silumin have been tested on the continuous bending machine of Schenck in Darmstadt. Tests of static strength and continuous impact tests have been used for comparison. The fatigue limit does not show any relation to the usual elastic limit nor to the elastic limit for stresses of very long duration (permanent rigidity). The fatigue limit of the refined alloys lies under the elastic limit of the annealed alloys above the elastic limit. Correspondingly, the influence of refining on fatigue is given as very low (10–20%), considerably lower than in the tests of Moore and Jasper. The fatigue limit is, in the present investigation, not exactly defined; the usual method of plotting the curves do not show whether the tested materials possess a tension limit below which fracture does not occur. Other tests on refinable aluminum alloys have so far always shown that even at several million load oscillations fractures still occur at reduced load which is shown clearly by the use of logarithmic coordinate paper. A further basic objection, so far too little considered in the literature, could be made, whether or not continuous bending tests can be compared with static tensile tests. The continuous impact tests still made are limited to a few definite impact tests and can, therefore, hardly be used as comparison. In general, the thorough and careful investigations to-day prove the unsatisfactory condition of the problem of fatigue. In how far the numerical values found can really serve as a guide to the engineer can still not be decided. The view offered by the results of this investigation that the "refinement" of aluminum alloys compared with permanent strength is in most cases an apparent one and therefore has no value for the engineer will hardly be accepted.—E. Fetz.

Galvanotechnik. By H. Krause. Verlagsbuchhandlung. Dr. Max Jänecke, Leipzig, Germany, 1928. Fifth Edition. 237 pages, 25 figs. Price, 5.40 R. M.

The author of this book states it is written for the practical man. Without assuming any theoretical knowledge in the field of electroplating and of electricity and chemistry, the book offers in all three fields that which is necessary to understand the proper working and utilization of the latest developments. The principles of these three branches of science are here offered in a form which make their use easy for systematic work. In the first part the electric current and its sources, the chemical notations, the atomic weights and the chemicals used in electroplating are treated. Then follows the electrochemical part, theory of electrolysis, current and bath conditions and their relation to the formation of the deposits. The following chapters deal with the practical part, installation of electroplating plants, treatment of the pieces before and after plating. Then follow the instructions for the different metallic deposits among which the most recent additions, chromium and cadmium only are taken into account. A large selection of recipes for electrolytic baths and information on ready-made baths is given. The eleventh chapter is devoted to deposits without external source of current which in many cases can still not be omitted to-day. Galvanoplastic is also treated very exhaustively. Data concerning special equipment for electroplating plants supplement the previous, similar chapter. The last two chapters deal with safety arrangements and first aid in poisoning, and the chemical testing of the electrolytes. The reader who wants really desirable information will appreciate what has been offered.—Max Hartenheim.

Vom Rost und vom Eisenschutz. By Manfred Rogg. Union, Deutsche Verlagsgesellschaft, Berlin, Germany, 1928. 119 pages, 49 figs., 10 tables. Price, 8.30 R. M.

The author aimed to give a review of the present status of the question of rust (corrosion). He first develops the principal points of the electrochemical theory of rust, and then treats the passive state of metals and the refining influence of oxygen. The theory developed by Kistianowski to explain the formation of an oxide film which causes passivity due to the Tichomiroff-polarization is thoroughly discussed by the author. The second part of the book devoted to the protection against rust deals merely with the protection by paints, in particular the rust-inhibiting pigments. More especially, the chemical and physical properties of the lead pigments are discussed. The author succeeded in clearly explaining the essential principles of the electrochemical theory of rust avoiding all unnecessary detail. The book will be a good guide for anyone who wants to study the complex questions of the phenomenon of rusting. The explanations are in general clear. The book is well made up, particularly pleasing are the micro-photographs—partly in colors—of color pigments.—G. Neuendorff.

Die Werkstoffe für den Bau Chemischer Apparate. By A. Furth. Otto Spamer, Leipzig, 1928. 216 pages, 72 figs., 2 plates. Price, 20 R. M.

The book aims to familiarize the chemist early in his career with the properties of the materials of his own field. This task is not an easy one considering the abundance of materials used and can be accomplished in this book only if the most necessary is treated concisely. The book contains two sections: one general part discussing physical, chemical and metallographic testing methods, and a special section on the production and the properties of non-metallic and metallic materials. For the sake of lucidity of the general section it would have been an advantage to have more diagrammatic illustrations instead of descriptions. The description of obsolete tests, for instance, the determination of refractoriness of ceramic masses in the Deville furnace, could well have been omitted to gain more space for a more detailed treatment and also completion of the method dealt with. For instance, the method for determination of density and true and apparent porosity of refractories are entirely omitted. In the second part, the materials are treated according to production, application and fitness. To save space it would have been better to treat the production as briefly as possible or even to omit it altogether since it is familiar to the chemist in this form usually from the handbooks of inorganic chemistry or chemical technology. In this way the properties could have been treated considerably more fully and illustrated with numerical information, corresponding to the proper intention of the book. If, for instance, the chapter on "Iron" is limited to only 19 pages and $^3/_4$ of that space is filled with the description of the occurrences in blast-furnaces or puddling it is not surprising that cast iron is discussed in only two or three sentences, and that the numerical values of strength and chemical properties are almost entirely missing. At that, quite a number of mistakes are made by the author. The tensile strength of forged steel with 0.9% C is given as 75 kg., one of the few figures which are given. It would have been better to give the iron-carbon diagram and discuss the properties by this diagram. In this manner the structural diagrams of Guillet for nickel and manganese steels would not have appeared as out of place as they do now. In spite of these objections, relating mostly to the question of arrangement, the book offers excellent information, especially on the resistance of materials to acid and alkali and will, therefore, be of considerable value. —Richard Rimbach.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

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United States Patents

Patents issued from June 18 to July 9, 1929, inclusive

Patent No.	Patentee, Subject of Invention, and Filing Date
1,717,419	W. Steinmann, Newark, N. J., assignor to General Motors Corp., Detroit, Mich. Method of drawing metal. May 9, 1924.
1,717,460	J. J. Mascuch, East Orange, N. J. Apparatus for electroplating metallic bands. July 1, 1927.
1,717,468	L. Schulte, Pittsburgh, Pa., assignor to Allegheny Steel Co., Brackenridge, Pa. Electroplating process. (Depositing Co-Cr alloys). May 29, 1926.
1,717,469	R. J. Shoemaker, Chicago, Ill., assignor to S. & T. Metal Co., Chicago, Ill. Bearing metal and method of making it. (Lead-sodium alloy.) Mar. 25, 1926.
1,717,482	L. Weidlich and M. F. Tracy, Stratford, and A. J. Flauder, Fairfield, Conn., assignors to The Weidlich Bros. Mfg. Co., Bridgeport, Conn. Method of manufacturing hollow ware of silver or the like. Oct. 10, 1923.
1,717,487	R. Armstrong, Ridgefield, N. J. Tube-pulling device. Aug. 4, 1927.
1,717,504	R. Furness. Ingot mold. Dec. 31, 1927.
1,717,513	A. J. Larcher, Chicago, Ill., assignor to Wyman-Gordon Co., Worcester, Mass. Process and apparatus for forging crank shafts. May 31, 1927.
1,717,530	E. Thomson, Swampscott, Mass., assignor to General Electric Co. Electric-arc welding. June 25, 1926, renewed Nov. 3, 1928.
1,717,575	E. L. Messler, Pittsburgh, Pa. Refractory composition for hot tops. Sept. 17, 1927, division of original application filed Dec. 8, 1926.
1,717,586	T. A. Schraishuhn, Coraopolis, Pa., assignor to Lewis Foundry & Machine Co. Rolling mill. Feb. 25, 1927.
1,717,588	G. A. Small, Philadelphia, Pa., assignor to Philadelphia Bronze Bearing and Tube Co. Method of lining tubes. May 13, 1924.
1,717,608	A. Kadow, Toledo, O., assignor to The Vacuum Casting Co., Toledo, O. Automatic casting machine. June 13, 1927.
1,717,612	R. L. McNeil, Oakland, Mich. Trimming die. Feb. 4, 1928.
1,717,615	W. H. Millspaugh, Sandusky, O., assignor to The Paper and Textile Machinery Co., Sandusky, O. Cast iron pipe and process of making pipe. Feb. 19, 1926.
1,717,634	H. Tormyn, Detroit, Mich., assignor to General Motors Corp., Detroit, Mich. Outside-flash-shearing machine. Aug. 1, 1927.
1,717,636	R. P. Vastine, Chicago, Ill. View passage for furnaces. Oct. 31, 1924.
1,717,643	H. M. Williams, Dayton, O., assignor to General Motors Research Corp., Detroit, Mich. Die for permanent moldings. July 2, 1927.
1,717,651	E. O. Beardsley and W. F. Piper, Chicago, Ill., assignors to The Beardsley & Piper Co., Chicago, Ill. Molding machine. Dec. 1, 1924.
1,717,652	E. O. Beardsley and W. F. Piper, Chicago, Ill., assignors to The Beardsley & Piper Co., Chicago, Ill. Molding machine. Feb. 13, 1926.
1,717,720	W. M. Martin and C. N. Church, Burlington, N. J. Reconditioning metal mold. Sept. 27, 1926.
1,717,735	G. C. Roy, Brooklyn, N. Y. Iron-bending machine. Apr. 15, 1927.
1,717,779	W. R. Hume, Melbourne, Victoria, Australia. Method of welding. Dec. 29, 1928, in Australia Dec. 16, 1927.
1,717,813	W. Steffe, Neukirchen, Germany, assignor to Freier Grunder Eisen- und Metallwerke G. m. b. H., Neukirchen, Germany. Melting furnace. Mar. 15, 1928, in Germany July 21, 1927.
1,717,820	B. F. Wallace, Brooklyn, N. Y. Compound for use in casting metals. July 15, 1925.
1,717,828	D. Baker, Swarthmore, Pa. Blast-furnace top. Apr. 21, 1926.
1,717,886	P. Lofy, deceased, Decatur, Ill., by C. M. Lofy and M. Lofy, executrices, Springfield, Ill. Brazing machine. Sept. 26, 1927.
1,717,914	D. J. Campbell, Muskegon Heights, Mich. Molding (Casting mold). Oct. 25, 1926.
1,717,916	D. J. Campbell, Muskegon, Mich. Mold and method of casting aluminum. Aug. 15, 1927.
1,718,061	E. F. Miller, Moores, Pa., assignor to Westinghouse Electric & Manufacturing Co. Method of manufacturing turbine blades. Nov. 30, 1927.
1,718,063	H. M. Naugle and A. J. Townsend, Canton, Ohio, assignors by mesne assignments to The American Rolling Mill Co., Middletown, Ohio. Continuous pickling apparatus. Dec. 19, 1924.
1,718,064	H. M. Naugle and A. J. Townsend, Canton, Ohio, assignors by mesne assignments to The American Rolling Mill Co., Middletown, Ohio. Scale breaker. May 24, 1927.
1,718,103	W. C. Baxter, Berkeley, Calif. Process of extracting mercury from cinnabar. Apr. 13, 1926.
1,718,172	W. E. Moore, Pittsburgh, Pa. Electric furnace. Sept. 7, 1916, renewed Oct. 3, 1928.
1,718,192	J. J. Crowe, Westfield, N. J., assignor to Air Reduction Co., Inc., New York, N. Y. Torch apparatus. Oct. 18, 1927.
1,718,210	P. A. E. Armstrong, Loudonville, N. Y., assignor to Ludlum Steel Co., Watervliet, N. Y. Process of making hollow drill rods. Jan. 12, 1922.
1,718,328	B. Broido, New York, N. Y., assignor to The Superheater Co., New York, N. Y. Method of making pipe structures. Apr. 25, 1923.
1,718,352	E. H. Guilford, Darwin, Calif., assignor to The Radiore Co., Los Angeles, Calif. Method of locating underground conductive bodies. Aug. 11, 1926.
1,718,364	F. P. Kobert, Springfield, Mass., assignor to Elektromatik Forging Machine Corp., New York, N. Y. Electrical heating and forging machine. May 13, 1927.
1,718,378	A. L. J. Queneau, New York, N. Y. Method of producing zinc. Feb. 3, 1927, renewed Nov. 20, 1928.
1,718,435	F. J. Rode, Chicago, Ill., assignor to Marquette Tool & Mfg. Co., Chicago, Ill. Hydraulic cushion for metal presses. Apr. 7, 1928.
1,718,491	F. M. Schad, New York, N. Y. Method of extracting mercury from cinnabar. Mar. 11, 1926.
1,718,502	E. Vanders, Heddernheim, near Frankfurt a.M., Germany. Copper-aluminum alloy. Mar. 31, 1927, in Germany Apr. 15, 1926.
1,718,552	W. H. Fluker, Thomson, Ga. Rotary grinding mill. July 15, 1927, renewed Sept. 7, 1928.
1,718,563	F. C. Kelley, Schenectady, N. Y., assignor to General Electric Co. Treatment of metals (cementation with chromium and silicon). Apr. 17, 1925.
1,718,642	J. A. Gann, Midland, Mich., assignor to The Dow Chemical Co., Midland, Mich. Light-metal alloy (Mg-Cu-Al-Cd). Oct. 18, 1922, renewed Sept. 1, 1926.
1,718,685	R. P. De Vries, Menands, and H. A. De Vries, Albany, N. Y., assignors to Ludlum Steel Co., Watervliet, N. Y. Ferro-aluminum alloy and method of making it. Apr. 25, 1927.
1,718,687	B. D. Enlund, Degerfors, Sweden, assignor to H. Enlund, Binghampton, N. Y. Method of determining the content of foreign substances in iron and steel. Aug. 16, 1927.
1,718,732	G. L. Danforth, Jr., Chicago, Ill., assignor by mesne assignments to Open Hearth Combustion Co., Chicago, Ill. Method of furnace operation. Oct. 8, 1921.
1,718,746	O. J. W. Lougheed, Portland, Oreg. Method of welding band saws. Aug. 6, 1928.
1,718,750	L. K. Marshall, West Somerville, Mass., assignor to Spencer Thermostat Co., Cambridge, Mass. Method of manufacturing bimetallic thermostats. Feb. 26, 1925.
1,718,753	L. E. Miller, Berkeley, Calif., assignor of 40 percent to W. J. Glover, San Francisco, Calif. Method and apparatus for forming pipe. Nov. 22, 1926.
1,718,779	E. F. Davis, Muncie, Ind., assignor to Warner Gear Co., Muncie, Ind. Heat-drawing furnace. June 16, 1926.
1,718,798	C. Nelson, Sheffield, England. Furnace. Oct. 23, 1926, in Great Britain Oct. 30, 1925.
1,718,806	B. Witting, Bonn a.Rh., Germany. Rolling of band iron, hoops and the like. Apr. 18, 1927, in Germany Apr. 23, 1926.
1,718,820	T. H. Heacock and D. W. Frease, Canton, Ohio. Rolling-mill bearings. Jan. 24, 1928.
1,718,825	E. Kirmse, Altrahlstedt, near Hamburg, and W. Schopper, Hamburg, Germany, assignors to American Metal Co., Ltd., New York, N. Y. Process for removing arsenic from ores, speiss and other metallurgical products. Oct. 29, 1927, in Germany Mar. 3, 1927.
1,718,870	A. Noell, Duisburg, Germany. Cooling bed (for rolled metal bars). Apr. 15, 1926, in Germany Apr. 23, 1925.
1,718,871	C. H. Nordell, Chicago, Ill. Method of and means for separating comminuted matter from the liquid in which it is immersed. Aug. 19, 1926.
1,718,917	C. R. Bowers, Los Angeles, Calif. Tempering, welding and brazing compound. Jan. 3, 1929.
Re 17,347	D. Cushing, Cambridge, Mass., assignor to The Barrett Co. Process for melting and refining of nonferrous metals. Oct. 12, 1927, original No. 1,556,591, filed Dec. 7, 1923, issued Oct. 13, 1925.
Re 17,362	J. R. McWane, Birmingham, Ala., assignor to McWane Cast Iron Pipe Co., Birmingham, Ala. Means for supporting core bars in flasks. Mar. 21, 1928, original No. 1,578,083, filed Dec. 12, 1924, issued Mar. 23, 1926.

Patent No.	Patentee, Subject of Invention, and Filing Date
Re 17,363	J. R. McWane, Birmingham, Ala., assignor to McWane Cast Iron Pipe Co., Birmingham, Ala. Means for supporting core bars in flasks. Nov. 21, 1928, original No. 1,578,083, filed Dec. 12, 1924, issued Mar. 23, 1926.
1,718,983	F. W. Schneible, Rome, N. Y., assignor to Rome Manufacturing Co., Rome, N. Y. Lock-joint metal tubing. Dec. 6, 1926.
1,719,056	W. G. Horsch, Coraopolis, Pa., assignor to Vulcan Detinning Co., Sewaren, N. J. Recovery of zinc. Dec. 2, 1926.
1,719,112	C. J. Holslag, South Orange, N. J., assignor to Electric Arc Cutting & Welding Co., Newark, N. J. Welding generator. Feb. 26, 1926.
1,719,113	C. J. Holslag, South Orange, N. J., assignor to Electric Arc Cutting & Welding Co., Newark, N. J. Welding tool. Feb. 29, 1928.
1,719,114	R. W. Hyde, Summit, N. J., assignor to Dwight & Lloyd Sintering Co., Inc., New York, N. Y. Igniter for sintering machines. May 21, 1927.
1,719,164	R. Bernhard, Allentown, Pa., assignor to Traylor Engineering Co., Allentown, Pa. Ball mill. Apr. 30, 1928.
1,719,167	G. D. Chamberlain, Ashland, Ky., assignor to R. T. Vanderbilt Co., Inc., New York, N. Y. Cleaning of metals, etc. Jan. 11, 1927.
1,719,168	G. D. Chamberlain, Ashland, Ky., assignor to R. T. Vanderbilt Co., Inc., New York, N. Y. Pickling of metals, etc. Jan. 11, 1927.
1,719,171	T. M. Davidson, Hatch End, England. Apparatus for separating minerals and other substances. Nov. 2, 1925, in Great Britain Jan. 1, 1925.
1,719,243	E. H. Shaff, Grand Haven, Mich., assignor to Wm. H. Keller, Inc., Grand Haven, Mich. Method of making piston rods. Aug. 10, 1925.
1,719,276	C. A. Overmire, San Francisco, Calif., assignor to The Western Gold & Platinum Works, San Francisco, Calif. High-temperature casting investment. May 23, 1928.
1,719,278	G. Powell, Michigan City, Ind., assignor to Pullman Car and Manufacturing Corp. Metal-breaking device. Aug. 15, 1924.
1,719,365	D. Gray and R. O. Bailey, Oneida, and W. S. Murray, Utica, N. Y., assignors to Oneida Community, Ltd., Oneida, N. Y. Tarnish-resisting silver and silver plate and processes for producing the same. Apr. 3, 1924, renewed Dec. 13, 1928.
1,718,452	H. C. Ryding, Birmingham, Ala. Soaking pit. Mar. 3, 1927.
1,719,453	H. C. Ryding, Birmingham, Ala. Soaking pit. Apr. 16, 1926.
1,719,463	W. H. Cole, Paris, France. Proofing metal, especially iron and steel, against rust. Feb. 28, 1927, in Great Britain Jan. 1, 1927.
1,719,464	W. H. Cole, Paris, France. Proofing of iron and steel against rust. Mar. 11, 1929, in Great Britain Jan. 29, 1929.
1,719,512	O. M. Krembs, Chicago, Ill. Dip brazing. Nov. 8, 1926.
1,719,529	S. C. Bliss, Kenmore, N. Y., assignor to American Radiator Co., New York, N. Y. Mold-ramming machine. Apr. 14, 1924.
1,719,534	M. F. Coolbaugh and J. B. Read, Denver, Colo. Treatment of sulfur-bearing minerals. June 27, 1924.
1,719,542	E. Gathmann, Baltimore, Md. Apparatus for molding ingots, Mar. 10, 1928.
1,719,543	E. Gathmann, Baltimore, Md. Ingot mold and ingot. Oct. 27, 1928.
1,719,544	E. Gathmann, Baltimore, Md. Method of making ingot mold Oct. 8, 1928, division of application filed Sept. 15, 1926.
1,719,558	O. L. Mills, Los Angeles, Calif., assignor to Mills Alloys, Inc., Los Angeles, Calif. Electric-arc furnace. Mar. 5, 1929.
1,719,564	C. H. Seymour, Kansas City, Mo. Magnetizable element and process of treating same. Apr. 4, 1927.
1,719,596	G. W. Davis, Seattle, Wash. Centrifugal casting machine. Sept. 29, 1927.
1,719,649	G. D. Chamberlain, Ashland, Ky., assignor to R. T. Vanderbilt Co., Inc., New York, N. Y. Pickling and cleaning of metal. Jan. 11, 1927.
1,719,650	G. D. Chamberlain, Ashland, Ky., assignor to R. T. Vanderbilt Co., Inc., New York, N. Y. Pickling of metals. Feb. 19, 1927.
1,719,657	H. Goldmann, Wilhelmsburg a.Elbe, Germany. Method of treating antimonial ores. Feb. 11, 1927, in Germany Mar. 29, 1926.
1,719,764	J. S. Gullborg, Chicago, Ill., assignor to Alemite Die Casting and Manufacturing Co., Chicago, Ill. Die-casting machine. June 8, 1927.
1,719,863	E. Wirz, Baden, Switzerland, assignor to Akt.-Ges. Brown Boveri & Cie., Baden, Switzerland. Furnace electrode carrier. Dec. 27, 1926, in Germany Jan. 7, 1926.
1,719,888	C. L. Ipsen and A. N. Otis, Schenectady, N. Y., assignors to General Electric Co. Electric furnace. Oct. 10, 1925.
1,719,958	L. W. Baney and E. G. Messer, Elma, Wash. Separating and concentrating mechanism. May 2, 1925.
1,719,963	W. B. Brady, New York, N. Y., assignor to A. C. Henry, Inwood, Long Island, N. Y. Composite electrical brush or contact and method of producing same. Mar. 29, 1926.
1,719,970	H. Eldridge, Oakland, Calif., assignor of $^{1}/_{16}$ to M. E. McGhee, Oakland, Calif., $^{1}/_{16}$ to M. E. Waldron, Albany, Calif., and by decree of court $^{7}/_{8}$ to M. K. Eldridge, widow of said H. Eldridge, deceased. Process of producing calcium carbide and pig iron. Mar. 8, 1927.
1,719,975	W. B. Gero, Bloomfield, N. J., assignor to Westinghouse Lamp Co. Annealed thorium and method of making the same. Mar. 1, 1926.
1,719,979	J. Ihlefeldt, Dessau, Germany, assignor to G. Polysius, Dessau, Germany. Crushing machine for hard materials. June 27, 1927, in Germany Feb. 4, 1926.
1,720,000	J. H. Ramage, Bloomfield, N. J., assignor to Westinghouse Lamp Co. Vibration and sag resistant filament. July 28, 1926.
1,720,024	D. H. Young, Berkeley, Calif., assignor to American Manganese Steel Co., Chicago, Ill. Ore mill and grinding element therefor. Dec. 3, 1927.
1,720,039	J. B. Green, Chicago, Ill. Welding rod. Dec. 10, 1925.
1,720,043	J. Harris, Cleveland, Ohio, assignor to The Harris Calorific Co., Cleveland, Ohio. Blowpipe. May 4, 1925.
1,720,055	P. J. Peyrachon, La Felguera, Spain. Apparatus for manufacturing iron and steel. May 2, 1927, in France July 13, 1926.
1,720,065	G. Verdickt, Ghent, Belgium. Metal packing (Pb-Sb-Zn). Oct. 22, 1927.
1,720,138	H. Neumark, Frankfurt a.M. Method for working up solutions obtained by leaching ores having been subjected to a chlorination roasting process. Nov. 9, 1927, in Germany Nov. 20, 1926.
1,720,177	J. R. Hatmaker, Paris, France. Method of protecting metal, wood and other substances and objects so protected. Nov. 19, 1927, in Great Britain Nov. 22, 1926.
1,720,215	D. Gray and R. O. Bailey, Oneida, and W. S. Murray, Utica, N. Y., assignors to Oneida Community, Ltd., Oneida, N. Y. Method of producing tarnish-resisting silver and silver plate. Nov. 5, 1923, renewed Sept. 27, 1928.
1,720,216	D. Gray and R. O. Bailey, Oneida, and W. S. Murray, Utica, N. Y., assignors to Oneida Community, Ltd., Oneida, N. Y. Tarnish-resisting silver plate and process for producing same. July 26, 1927.
1,720,264	R. de Robillard, Tananarive, Madagascar. Flotation machine for graphite and other minerals. July 19, 1927, in France Aug. 9, 1926.
1,720,286	G. Michel, Bagneux, France. Process for the protection of the surface of baths of easily oxidizable metals such as magnesium. Aug. 2, 1926, in France Aug. 18, 1925.
1,720,290	H. J. F. Philipon, St. Etienne, France, assignor to The Societé Anonyme "l'Air Chaud," St. Etienne (Loire), France. Method of operating molten slag gas producers. Jan. 31, 1923, in Belgium Mar. 8, 1922.
1,720,312	F. M. Becket, New York, N. Y. Anode for chromium plating. Oct. 14, 1926.
1,720,313	F. M. Becket, New York, N. Y. Anode for chromium plating. Oct. 14, 1926.
1,720,335	H. P. L. Laussucq, Reading, Pa. Bending machine. Nov. 4, 1926.
1,720,345	M. Peters, Duisburg, Germany, assignor to Wellman Seaver Rolling Mill Co., Ltd., London, England. Apparatus for the manufacture of metal tubes and other tubular articles. Dec. 13, 1924, in Great Britain Jan. 26, 1924.
1,720,353	G. Schneider and F. A. Welsmiller, Saginaw, Mich. Tappet (chilled white iron surface and soft gray iron core). Dec. 12, 1927.
1,720,354	K. W. Schwartz, New York, N. Y., assignor to Chromium Corporation of America. Method and apparatus for electrodepositing chromium. Apr. 30, 1927.
1,720,356	A. R. Willard, East Cleveland, Ohio, assignor to Willard Storage Battery Co., Cleveland, Ohio. Coating material for metal molds. Sept. 27, 1926.
1,720,357	A. R. Willard, East Cleveland, Ohio, assignor to Willard Storage Battery Co., Cleveland, Ohio. Automatic casting machine. Nov. 1, 1926.
1,720,366	F. C. Langenberg, Watertown, Mass., assignor of one-half to T. C. Dickson, Watertown, Mass. Method of making hollow metallic articles. Dec. 11, 1925.
1,720,375	L. J. Parker, Chicago, Ill., assignor to Quality Hardware & Machine Co. Telescopic punch for forming tubes. Aug. 26, 1927.
1,720,383	E. C. Smith, Massillon, Ohio, assignor to Central Alloy Steel Corp., Massillon, Ohio. Ingot and mold for making same. Dec. 29, 1924.
1,720,436	G. Pistor, Leipzig, Germany, assignor to I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. Process of refining magnesium and its alloys. Nov. 8, 1927, in Germany Nov. 13, 1926.
1,720,446	R. Sarazin, Neuilly-sur-Seine, France. Electric-arc welding transformer and controlling device. June 8, 1927, in France June 12, 1926.
1,720,525	K. T. Potthoff, Brooklyn, N. Y., assignor to U. S. Galvanizing & Plating Equipment Corp. Apparatus for treating pipes, bars, etc. Apr. 18, 1925.
1,720,570	R. H. Pratt, Pelham Manor, N. Y. Spot welder. Oct. 22, 1927.
1,720,611	J. D. Smith, Dunedin, Otago, New Zealand. Apparatus relating to molding units. Sept. 20, 1923.

Austrian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
113,306	K. Emmel, Mülheim a.Ruhr, Germany. Process for making cast iron with low carbon content and high mechanical properties. Jan. 15, 1929.
113,453	K. W. Zschocke, Aussig a.Elber, Czechoslovakia. Process for making wires of tungsten, molybdenum and other refractory metals. Jan. 15, 1929.
113,343	H. Barthel, Schweinfurt a.M., Germany. Process for casting and pressing annular bodies. Jan. 15, 1929.
113,358	Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. Supporting device for the pouring troughs of centrifugal casting molds. Jan. 15, 1929.
113,359	International De Lavaud Mfg. Corp., Ltd., Toronto, Ont. Steel mold and method of making. Jan. 15, 1929.
113,360	Machinenfabrik Esslingen, Esslingen, Würt., Germany. Process for making low-carbon gray cast iron. Jan. 15, 1929.
113,314	F. Sigmund, Vienna, Austria. Process for making porous metallic bodies. Jan. 15, 1929.
113,313	W. S. Smith, Benchams; H. J. Garnett, Lymne; and J. A. Holden, Sunnyside, England. Magnetic iron-nickel alloy. Jan. 15, 1929.
113,308	Siemens & Halske Akt.-Ges., Berlin, Germany and Vienna, Austria, assignee of M. Hosenfeld, B. Stein, G. Hänsel, and B. Charl. Process and apparatus for refining copper or copper alloys. Jan. 15, 1929.
113,317	Firma Neurath, Vienna, Austria, assignee of T. Kittl, Vienna, Austria. Process for working up the anode slime formed in the electrolytic recovery of tin from tin-bearing lead alloys. Jan. 15, 1929.
113,280	Siegener Eisenbahn-bedarf Akt.-Ges., Siegen. Process and apparatus for pressing hollow bodies. Jan. 15, 1929.
113,511	F. Krupp Akt.-Ges., Essen, Germany. Process for making tools of sintered hard metal alloys. Jan. 15, 1929.
113,286	F. Jordan, Wickede a.Ruhr, Germany. Method of metallically joining the seams of aluminum plated sheet iron. Jan. 15, 1929.
113,296	International De Lavand Corp., Ltd., Toronto, Ont. Process for surface-hardening smooth iron and steel objects. Jan. 14, 1929.

Patent No.	Patentee, Subject of Invention, and Filing Date
113,851	F. Krupp Grusonwerke Akt.-Ges., Magdeburg-Buckau, Germany. Rollway for cooling beds. Feb. 15, 1929.
113,655	Firma Heinrich Lanz, Mannheim, Germany. Process for making high-quality gray cast iron. Mar. 15, 1927.
113,665	Siemens-Elektrowärme G. m. b. H., Sörnewitz, near Meissen, Germany, assignee of K. Tamele, Berlin-Wilmersdorf, Germany. Method of operating bright-annealing furnaces. Feb. 15, 1929.
113,658	F. M. Schad, New York, N. Y. Wet process for obtaining mercury from sulfidic ores. Feb. 15, 1929.
113,661	Reymersholms Gamla Industri Aktiebolag, Hälsingborg, Sweden. Process of obtaining valuable constituents from chlorinated roasted pyrites. Feb. 15, 1929.
113,659	R. Dufour and M. Gliksman, Paris, France. Heating element with spiral windings, especially for electric high-frequency induction furnaces. Feb. 15, 1929.
113,660	British Metallising Co., Ltd., London, England. Process for producing a metallic coating on sulfur-bearing castable materials. Feb. 15, 1929.
113,621	F. Krupp Akt.-Ges., Essen, Germany. Process for increasing the yield point of hollow bodies made of alloy steels, whose yield point cannot be raised by heat treatment, especially austenitic steels. Feb. 15, 1929.

British Patents

Specifications Open to Public Inspection in Great Britain.

Patent No.	Patentee, Subject of Invention, and Filing Date
312,140	Langendorf Watch Co. Manufacture of electrical contact pins or plugs. May 21, 1928.
312,141	Langendorf Watch Co. Electrical contact pins or plugs. May 21, 1928.
312,349	F. Krupp Akt.-Ges. Nitrated steel articles. May 25, 1928.
312,352	Pipe & Tube Bending Corporation of America. Method of an apparatus for reducing the cross-sectional area of bars. May 25, 1928.
312,358	Elin Akt.-Ges. für Elektrische Industrie. Device for mechanically operated welding. May 25, 1928.
312,166	E. Weir. Method of producing malleable metal pipes. May 21, 1928.
312,361	F. Krupp Akt.-Ges. Process for eliminating from pig iron noxious constituents such as phosphorus and sulfur without oxidation of the carbon in the iron. May 25, 1928.
312,237	International General Electric Co., Inc. Means for feeding the wire in electric arc welding machines. May 22, 1928.
312,193	Akt.-Ges. für Tiefbohrtechnik und Maschinenbau vorm. Trauzl & Co. Cutting and welding machines. May 19, 1928.
312,279	H. J. Spanner and U. Doring. Method of applying coatings to electrodes and other bodies. May 3, 1928.
312,285	E. A. Rosengrens Kassaskapsfabriks Aktiebolaget. Method and machine for welding together radiator sections. May 23, 1928.
312,324	J. Doubs. Process for rolling thin plates. May 24, 1928.
312,369	W. Kurze. Process and apparatus for filling molds with sand or the like. May 24, 1928.
312,629	I. G. Farbenindustrie Akt.-Ges. Manufacture and production of metal carbonyls. May 29, 1928.
312,667	A. Folliet and N. Sainderichin. Process for treating ores. May 30, 1928.
312,917	H. J. M. E. Clerc. Process for refining nickel, copper and copper-nickel alloys. June 1, 1928.
312,918	F. Krupp Akt.-Ges. Method of manufacturing seamless forged receptacles for high pressures. June 2, 1928.
312,924	L. Ughetti-La Corsa. Method for recovery of tin from tin-plate scraps. June 2, 1928.
312,932	Dr. F. Neumann. Arrangement for attaining high temperatures by means of electric heating resistances. June 2, 1928.
312,940	Roessler & Hasslacher Chemical Co. Process for making electrodes. June 1, 1928.
312,988	Electric Furnace Co., Ltd. Method of and apparatus for annealing metal strips. June 4, 1928.
313,121	P. L. J. Miguet and M. P. Perron. Electric furnaces. June 7, 1928.
313,044	E. F. Northrup. Electric induction furnaces. June 5, 1928.
312,996	Verein für chemische und metallurgische Produktion. Pickling of iron and steel. June 4, 1928.
313,166	L. Ughetti-La Corsa. Electrolyser for separation of tin from tin salt solutions. June 9, 1928.
313,430	Societé Miniere and Metallurgique de Penarroya. Process for the treatment of zinc ores. June 11, 1928.
313,582	Erie City Iron Works. Method of and apparatus for pulverizing and treating materials. June 16, 1928.
313,583	Mannesmannröhren-Werke. Method of and means for centrifugal casting of metal blocks. June 15, 1928.
313,584	Electrical Research Products, Inc. Magnetic materials. June 15, 1928.
313,434	F. Krupp Akt.-Ges. Method of welding iron and iron alloys. June 11, 1928.
313,487	I. G. Farbenindustrie Akt.-Ges. Process of welding magnesium alloys. June 12, 1928.
313,597	Trent Process Corp. Process for the reduction of iron ores. June 16, 1928.
313,489	Vereinigte Aluminium-Werke Akt.-Ges. Method of removing gases from molten light metals such as aluminum and its alloys. June 12, 1928.
313,599	Chemisches Werk Zürich Akt.-Ges. Process and apparatus for cleaning articles of metal or other material. June 15, 1928.
313,530	International General Electric Co., Inc. Electric resistance seam welding machines. June 13, 1928.
313,619	F. Krupp Akt.-Ges. Method of producing shaped bodies for tools, of material difficult to work such as carbides, their alloys and the like. June 15, 1928.
313,856	Hirsch Kupfer- und Messing-Werke Akt.-Ges. Method of and apparatus for melting oxidizable material. June 16, 1928.
313,858	L. Surbelle. Production of zinc and the like metals. June 15, 1928.

British Patents

Complete Specifications Accepted

Patent No.	Patentee, Subject of Invention, and Filing Date
287,046	G. Michel. Process for protecting magnesium and its alloys. (Addition to No. 249,484.) Mar. 12, 1927.
285,513	Allgemeine Elektrizitäts Gesellschaft. Method of and means for electrical resistance welding. Feb. 18, 1927.
285,824	I. G. Farbenindustrie Akt.-Ges. Electrolytic production of metals and apparatus therefor. Feb. 21, 1927.
306,108	D. Guggenheim, M. Guggenheim, S. R. Guggenheim, S. Guggenheim, J. K. MacGowan, and E. A. C. Smith (trading as Guggenheim Bros.). Treatment of tin-bearing materials. Feb. 16, 1928.
302,994	F. Krupp Akt.-Ges. Iron-nickel alloy. Dec. 24, 1927.
296,303	International General Electric Co., Inc. Electrical determination of irregularities in the structure of massive metallic bodies. Aug. 27, 1927.
305,623	Langbein-Pfanhauser-Werke Akt.-Ges. Drum apparatus for galvanizing and other purposes. Feb. 8, 1928.
287,912	J. H. Gravell and A. Douty. Processes for controlling the action of pickling acids on metals. Mar. 29, 1927.
296,722	G. Voight. Devices for catching cuttings and the like of precious metals being worked by hand. Sept. 6, 1927.
294,639	A. Dawans. Furnace for fusing finely-divided materials and process for agglomerating dust from blast furnaces. July 29, 1927.
299,879	G. Bühler. Casting of hollow metal bodies. Nov. 4, 1927.
300,969	P. Odam. Process for soldering aluminum. Nov. 21, 1927.
305,469	Hartstoff-Metal Akt.-Ges. Hametag. Beaters for impact pulverizers. Feb. 4, 1928.
300,213	Mag Maschinenfabrik Akt.-Ges. Geislingen. Grinding or crushing mills. Nov. 8, 1927.
282,671	National Malleable and Steel Castings Co. Methods of making malleable iron castings. Dec. 23, 1926.
306,882	T. Bader. Heating means for type-casting or compositing machines. Feb. 27, 1928.
291,437	Siemens-Schuckert-Werke Akt.-Ges. Annealing furnaces. June 3, 1927.
295,986	Vereinigte Stahlwerke Akt.-Ges. Manufacture of rails and other rolled articles. Aug. 22, 1927.
292,936	S. Deiches. Bearing metals of the ternary system copper, antimony, lead. June 24, 1927.
305,023	Schloemann Akt.-Ges. Control of machines for shearing metal bars. Jan. 28, 1928.
312,110	J. Richings and P. R. Gillard. Safety device for application to tin-plate or other rolling mills. Feb. 18, 1928.
312,126	H. D. Elkington (Meehanite Metal Corp.). Manufacture of cast iron. Feb. 20, 1928.
312,395	Electro Bleach and By-Products, Ltd., J. Hollins and D. Jepson. Electrodeposition of metals. Feb. 25, 1928.
312,401	J. Robinson. Cupola furnaces. Feb. 27, 1928.
312,441	General Electric Co., Ltd., and R. W. W. Sanderson. Manufacture of nickel-iron alloys. Mar. 29, 1928.
312,478	C. Chaffer and H. Hargreaves. Coating for metals. May 12, 1928.
312,555	H. C. Hall and T. F. Bradbury. Aluminum alloy (Addition to No. 300,098). Sept. 11, 1928.
312,571	J. H. Friedman. Method of making forgings. Nov. 1, 1928.
312,403	Electro Bleach and By-Products, Ltd., J. Hollins and D. Jepson. Electrodeposition of metals. Feb. 25, 1928.
312,700	J. A. Jack. Refractory materials. Mar. 6, 1928.
312,758	A. B. Smith and C. R. Smith. Foundry molding boxes. Apr. 16, 1928.
312,759	C. Hummel. Process and apparatus for case-hardening iron. Apr. 16, 1928.
312,826	J. G. Gaunt (Societa Alti Forni, Fonderi, Acciaierie e Ferriere Franchi Gregorini). Machines for the centrifugal casting of tubes in metal by means of rotating tubular molds.
312,834	F. L. Duffield. Briquetting or consolidating sponge iron granules. June 25, 1928.
312,838	C. A. Midgley and J. T. Goodwin. Means for utilizing molten slag and producing cast slag in a form suitable particularly for use in road making. June 29, 1928.
312,839	Wellman Seaver Rolling Mill Co., Ltd., and S. Smith. Reeling and polishing mills. June 30, 1928.
312,845	C. A. Boulton. Metallic alloy. July 11, 1928.
312,865	H. Möller. Drawing process for the production of round rods of steel, silver steel, tool steel, high-speed tool steel, free from pores and possessing a high brilliant polish and absolutely uniform cross-section. Aug. 13, 1928.
312,882	C. R. B. Smith and J. A. Hunter and Co., Ltd. Soldering. Sept. 18, 1928.
312,886	G. Morgan. Annealing pot. Oct. 13, 1928.
312,598	Electro Bleach and By-Products Co., Ltd., J. Hollins and D. Jepson. Electrodeposition of metals. Feb. 25, 1928.
312,599	Electro Bleach and By-Products Co., Ltd., J. Hollins and D. Jepson. Electrodeposition of metals. Feb. 25, 1928.
312,600	Electro Bleach and By-Products Co., Ltd., J. Hollins and D. Jepson. Electrodeposition of metals. Feb. 25, 1928.
313,111	E. Grien. Circuit arrangement for use with high-frequency currents. Mar. 7, 1928.
313,260	F. L. Duffield. Apparatus for the production of clocks or briquettes. Apr. 17, 1928.
313,264	H. A. Waldrich Ges. and P. Eyermann. Process for increasing the percentage of weight of output in rolled or forged finished metallic goods with preliminary cleaning of the prematerial to be rolled or forged, by turning or the like. Apr. 20, 1928.
313,300	A. H. Marks and P. Russell (American Machine and Foundry Co.). Metal foil. May 29, 1928.
313,389	A. E. White (Budd Wheel Co.). Rolling of wheel bodies or the like. Oct. 12, 1928.
311,393	Annener Gussstahlwerk Akt.-Ges. Making of castings. May 12, 1928.

Patent No.	Patentee, Subject of Invention, and Filing Date
313,394	P. C. Blair. Machine or apparatus for bending metal strips. Oct. 29, 1928.
313,398	R. Haddan, W. H. Beatty and W. H. Beatty (trading as Beatty Palmer & Beatty) Centrifugal casting machines. Dec. 3. 1928.
313,471	Sir R. A. Hadfield. Alloys. Mar. 10, 1928.
313,656	W. A. Cloud. Grinding, crushing, pulverizing or disintegrating mills. Mar. 16, 1928.
313,690	E. C. Loesche. Crushing mills. Apr. 14, 1928.
313,724	General Electric Co., Ltd., and G. W. Gorvin. Securing rivets or the like in cast or molded articles. May 21, 1928.
313,728	Woodall-Duckham (1920), Ltd., and Sir Am. M. Duckham. Method of and apparatus for repairing heated structures such as furnaces, retorts and the like. May 24, 1928.
313,761	Stephenson, Blake & Co., Ltd., and H. F. B. Stephenson. Receptacle for collecting the dross on type-casting metals and the like. June 26, 1928.
313,797	L. Jones. Method and apparatus for the reduction of impurities in molten metals. Aug. 1, 1928.
313,844	E. C. Loesche. Crushing mills. Apr. 14, 1928.
313,845	E. C. Loesche. Crushing mills. Jan. 7, 1928.

Canadian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
290,240	R. E. Frickey, San Francisco, and A. S. Kalenborn, Redwood City, Calif. Welding system (railroad rails). Nov. 24, 1925.
290,273	E. G. T. Gustafsson, Stockholm, Sweden. Iron and steel manufacture. Nov. 20, 1926.
290,316	W. L. Schulenberg, Dunkirk, N. Y. Heat processing apparatus. Oct. 10, 1928.
290,328	G. K. Williams, Port Pirie, South Australia. Lead bullion refining process. Feb. 14, 1927.
290,329	G. K. Williams, Port Pirie, South Australia. Lead bullion refining process. Feb. 14, 1927.
290,343	The Automotive Engineering Co., Ltd., Twickenham, assignee of E. C. Lewis, Teddington, both of Middlesex, England. Permanent metal founding mold. Sept. 10, 1928.
290,379	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., assignee of W. Busch, Köln-Deutz and E. Noack, Wiesdorf, Germany. Potassium manufacture. June 18, 1928.
290,388	The Grasselli Chemical Co., Ltd., Hamilton, Ont., assignee of The Grasselli Chemical Co., Cleveland, Ohio, assignee of L. R. Westbrook and H. H. Bond, Cleveland, Ohio. Electroplating (cadmium). Dec. 30, 1927.
290,389	The Guggenheim Bros., assignee of A. H. Fischer, New York, N. Y. Flotation process. Apr. 11, 1927.
290,394	C. F. Kenworthy, Inc., Waterbury, assignee of C. F. Kenworthy, Woodbury, Conn. Annealing furnace. June 8, 1927.
290,411	The Mergenthaler Linotype Co., assignee of D. S. Kennedy, Brooklyn, N. Y. Typographical casting machine. Nov. 15, 1928.
290,419	The Morgan Construction Co., assignee of G. H. Isley, both of Worcester, Mass. Furnace mechanism. Nov. 18, 1926.
290,426	The Ohio Brass Co., Mansfield, Ohio, assignee of The Ohio Insulator Co., Barberton, Ohio, assignee of A. O. Austin, North Barberton, Ohio. Casting method. July 25, 1928.
290,444	La Société Électrométallurgique de Montricher, assignee of P. L. J. Miguet, Montricher, near St. Julien de Mauriemme, Savoy, France. Electric furnace stirring apparatus. Oct. 31, 1926.
290,459	F. Trostler and Chemische Fabrik Johannisthal G. m. b. H., Berlin-Rudow, assignee of one-half interest. Copper and nickel recovery. Aug. 9, 1927.
290,554	The American Manganese Steel Co., assignee of F. A. Fahrenwald, both of Chicago, Ill. Steel processing (strain hardening of manganese steel). Aug. 8, 1928.
290,555	The American Sheet and Tin Plate Co., assignee of C. W. Bennett, both of Pittsburgh, Pa. Sheet and plate manufacture. July 22, 1927.
290,661	The Granular Iron Co., New York, N. Y., assignee of K. Smith, Detroit, Mich. Steel manufacture. Apr. 5, 1927.
290,901	W. H. Cole, Paris, France. Proofing metal. Dec. 29, 1927.
290,902	W. H. Cole, Paris, France. Proofing metal. Dec. 29, 1927.
290,915	J. Horne, Fairfield, Ala. Slag pocket cleaner. Aug. 23, 1928.
290,971	Aluminium Industrie Akt.-Ges., Neuhausen, assignee of J. Weber, Neuhausen and H. Hauser, Wilchingen, all of Switzerland. Production of aluminum. Jan. 18, 1927.
290,973	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of C. L. Inglefield, Bellevue and H. H. Giles, Monessen, Pa. Tin plate cleaning machine. Dec. 15, 1927.
290,974	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of A. R. McArthur, Gary, Ind. Hot mill catcher. Jan. 21, 1928.
290,975	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of A. R. McArthur, Gary, Ind. Sheet making apparatus. June 20, 1928.
290,977	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of J. F. Howe, Worcester, Mass. Wire manufacture. Jan. 17, 1927.
290,978	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of W. F. Munford, Worcester, Mass. Wire manufacture. Jan. 17, 1927.
290,979	The American Sheet and Tin Plate Co., Pittsburgh, Pa., assignee of P. Jepsen, Worcester, Mass. Electro-galvanizing apparatus. Mar. 12, 1927.
291,027	The Ohio Rubber Co., Cleveland, Ohio, assignee of B. Bronson, Lakewood, Ohio. Composite steel and rubber article. June 6, 1928.
290,691	M. Douteur, La Plaine St. Denis, France. Ingot manufacture. June 29, 1927.
290,696	A. W. Fahrenwald, Houghton, Mich. Ore flotation machine. Mar. 14, 1928.
290,706	T. R. Haglund, Stockholm, Sweden. Metal manufacture. Oct. 20, 1926.
290,755	J. D. Travis, Salt Lake City, Utah. Casting machine. Sept. 14, 1927.
290,760	E. C. Washburn, Englewood, N. J. Ingot casting machine. May 5, 1928.
290,771	The American Chemical Paint Co., Carrollville, Wis., assignee of J. G. Schmidt, Milwaukee, and H. R. Lee, South Milwaukee, Wis. Iron and steel dissolution preventing process (prevention of dissolution in sulfuric acid). Oct. 24, 1927.
290,790	The Canadian Westinghouse Co., Ltd., Hamilton, Ont., assignee of L. Smede, Pittsburgh, Pa. Carbonized iron anode. Dec. 24, 1928.
290,801	E. I. du Pont de Nemours & Co., assignee of E. K. Bolton, both of Wilmington, Del. Ore flotation method. May 4, 1927.
290,806	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., assignee of H. Schaladebach, Dessau, and H. Hahle, Dessau-Ziebigk. Lacquer for coating on metal surfaces. Oct. 17, 1928.
290,812	The Hume Steel, Ltd., assignee of W. R. Hume, Melbourne, Victoria, Australia. Arc welding process. Jan. 2, 1929.
290,813	Hüttenwerke Tempelhof A. Meyer, assignee of M. Speichert, both of Berlin-Tempelhof, Germany. Tin, antimony, lead and copper processing. Feb. 11, 1928.
290,822	The Minerals Separation North American Corp., assignee of W. Trotter, both of New York, N. Y. Froth flotation concentration of ores. Apr. 25, 1927.
290,827	The New Jersey Zinc Co., New York, N. Y., assignee of F. G. Breyer and E. H. Bunce, Palmerton, Pa. Built-up vertical zinc retort of brick. July 27, 1927.
290,844	La Société Électrométallurgique de Montricher, assignee P. L. J. Miguet, both of St. Julien de Maurienne, Savoy, France. Furnace feed apparatus. Dec. 27, 1927.
290,848	Victoria-Werke Akt.-Ges., assignee of J. Schmitt, both of Nürnberg, Germany. Soldering method. Aug. 3, 1928.

French Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
663,203	E. Kuhrmeier. Gas-tight metallic lining for high-pressure gas compressors. Oct. 30, 1928.
662,900	Morgan Construction Co. Selective handling of metal bars or billets. Oct. 25, 1928.
662,960	H. G. Flodin. Process for converting oxidized metals into metallic sponge. Oct. 26, 1928.
662,961	H. G. Flodin. Process for the production of ferro-silicon. Oct. 26, 1928.
663,037	Société Nantaise de Fonderies et de Constructions Mécaniques. Manufacturing process for producing resistant copper alloys. Feb. 16, 1928.
663,173	I. G. Farbenindustrie Akt.-Ges. Process for making very resistant silver-base surfaces. Oct. 30, 1928.
663,027	P. Dannely. Process and devices for making solid and hollow castings. (Improvement of No. 651,189.) Feb. 15, 1928.
663,049	J. Van Bosse. Process for degasifying and cleaning the surfaces of metals by means of an electric current in a vacuum. Oct. 26, 1928.
663,181	A. Despierre, E. Devulder and E. Mascart. New pickling process. Oct. 30, 1928.
663,152	Société Anonyme pour l'Industrie de l'Aluminium. Process for recovering pure aluminum electrolytically from crude aluminum, alloys, etc. Oct. 29, 1928.
663,210	J. Harden and H. T. Tillquist. Device for melting metals. Oct. 30, 1928.
663,297	Societé Aubert Duval Freres. Process for protecting certain parts of nitrized steel against hardening. Nov. 2, 1928.
663,303	Uddesholms Aktiebolag. Improvement to the process for annealing wire or band hoops made of iron or other metals. Nov. 2, 1928.
663,326	R. Van Zelewski. Process for treating zinc ores. Nov. 2, 1928.
663,332	National Processes, Ltd. Improvements to machines for sintering or roasting ores. Nov. 2, 1928.
663,347	H. E. Fosset, Moumea, New Caledonia. Process for the chemical treatment of nickel silicates. July 3, 1928.
663,504	I. G. Farbenindustrie Akt.-Ges. Process for preparing completely homogeneous alloys of lead with alkali or alkaline earth metals. Nov. 3, 1928.
663,600	F. Krupp Gruson-Werke Akt.-Ges. Device for unloading the collector bars of cooling tables of rolling mills. Nov. 6, 1928.
663,601	F. Krupp Akt.-Ges. Iron-nickel alloy. Nov. 6, 1928.
663,626	K. Geisecke. Process for treating rolled steel products prior to cold working. Nov. 7, 1928.
663,637	Société Métallurgique de Knutange (S. A.). Process for increasing the citric acid solubility of Thomas slag. Nov. 7, 1928.
663,661	L. M. Duruelle. Continuous furnace for heating rivets or like pieces. Nov. 8, 1928.
663,246	A. M. Erichsen. Chill mold for casting metals not containing iron. Oct. 31, 1928.
663,273	H. W. Bundy. Metallic tubing. Oct. 31, 1928.
663,274	H. W. Bundy. Apparatus for making multi-layer metal foil. Oct. 31, 1928.
663,343	H. Leiser. Process for burnishing chromium plated iron or aluminum objects. July 21, 1928.
663,665	The National Machinery Co. Process for making forgings. Nov. 8, 1928.
663,666	The National Machinery Co. Process and means for piercing holes in pieces of metal. Nov. 8, 1928.
663,667	The National Machinery Co. Process for making forged tubing. Nov. 8, 1928.
663,265	The Dunlop Rubber Co., Ltd. Improvements in the galvanoplastic metallization of annular objects and apparatus therefor. Oct. 31, 1928.
663,423	P. E. Bunet and Société Anonyme Acieries de Gennevilliers. Improvements in magnetic-core induction furnaces. June 17, 1928.
663,424	P. E. Bunet and Société Anonyme Acieries de Gennevilliers. Electric heating device. Feb. 17, 1928.

Patent No.	Patentee, Subject of Invention, and Filing Date
663,464	P. E. Bunet and Société Anonyme Acieries de Gennevilliers. Improvements to induction furnaces. Feb. 23, 1928.
663,541	Siemens-Schuckertwerke Akt.-Ges. Electric annealing furnace. Nov. 5, 1928.
663,605	E. Bornand and H. Schlaepfer. Electric furnace fed by high-frequency currents. Nov. 6, 1928.
663,610	S. A. des Etablissements A. Valuy, Lyons, France. Improvement of refractory materials. Nov. 7, 1928.
663,895	F. Krupp Grusonwerk Akt.-Ges. Process and device for separating bodies, particularly crude mine products. Nov. 13, 1928.
663,707	E. Brumm. Improvements to machines for casting and molding metals under pressure. Nov. 9, 1928.
663,847	Société d'Etudes et de Constructions Métallurgiques. Charging device for shaft furnaces. Nov. 12, 1928.
663,899	Vereinigte Stahlwerke Akt.-Ges. Process for increasing the yield point and tensile strength of low-carbon steels. Nov. 13, 1928.
663,942	P. Marx. Cupola. Nov. 14, 1928.
663,977	Siemens Schuckertwerke Akt.-Ges. Cooling device for furnaces for annealing bare objects. Nov. 15, 1928.
663,996	C. Philippossian. Inalterable white alloy. Nov. 15, 1928.
664,029	S. A. Fonderies et Forges de Crans. Process for casting liquid material in a mold and installation for working the same. Nov. 15, 1928.
664,070	Zimmermann and Jansen G. m. b. H. Bricks for air heaters. Nov. 16, 1928.
663,757	D. Perron. Portable forge. Nov. 10, 1928.
663,768	Bendix Brake Co. Improvement to electric welding machines. Nov. 10, 1928.
663,837	N. Collard. Foundry flask pin. Nov. 12, 1928.
663,873	M. V. N. Leroy. Sand slinger for molding machines. Nov. 13, 1928.
663,873	Vereinigte Stahlwerke Akt.-Ges. Process for making reinforced pipe ends of at least triple wall thickness, and device used for this. Nov. 14, 1928.
664,068	W. H. Millspaugh. Cast iron pipe. Nov. 16, 1928.
663,714	Langbein-Pfanhauser-Werke Akt.-Ges. Drum apparatus for electroplating loose objects. Nov. 8, 1928.
663,831	Siemens & Halske Akt.-Ges. Coil arangement for ironless induction furnaces. Nov. 12, 1928.
664,160	R. Bruchert and H. Fort. Improvements to electric furnaces. Nov. 19, 1928.
664,286	Metropolitan Vickers Electric Co., Ltd. Aluminum-silicon alloys. Nov. 20, 1928.
664,458	I. G. Farbenindustrie Akt.-Ges. Process for using cerium in the manufacture of iron and steel. Nov. 22, 1928.
664,476	R. von Wulfing. Process for treatment of metals and alloys with agents containing cyanogen. Nov. 23, 1928.
664,498	Demag Akt.-Ges. Electrically driven delivery table for rolling mills. Nov. 23, 1928.
664,499	Demag Akt.-Ges. Process for charging electric melting furnaces. Nov. 23, 1928.
664,504	J. Weiss. Light alloy and industrial products made of it. Nov. 23, 1928.
664,565	A. Gourgaud. Device for cementation of cast metal scrap. Nov. 22, 1928.
664,651	Etablissments Boudin et Grangette. Improvements to annealing processes and to annealing furnaces. Nov. 27, 1928.
664,217	Berg-Heckmann Selve Akt.-Ges. Device for introducing the sizing mandrel into tubing to be drawn. Oct. 18, 1927.
664,580	L. J. B. Pillon. New process for wet galvanizing. Nov. 6, 1928.
664,662	Witkowitzer Bergbau und Eisenhütten Gewerkschaft and E. Keller. Mandrel for tube rolling mills. Nov. 27, 1928.
664,253	Metallgesellschaft Akt.-Ges. Process for obtaining thick and coherent electrolytic deposits of metals. Oct. 27, 1928.
664,559	Dr. Alex. Wacker Ges. für Electrochemische Industrie G. m. b. H. Method of mounting electric furnace electrodes. Nov. 24, 1928.
665,179	American Cyanamide Co. Improvements to flotation agents. May 8, 1928.
664,847	A. Pacz. Alloy. Nov. 29, 1928.
664,893	S. A. Métallurgique d'Aubrives et Villerupt. Improvements to devices for obtaining uniform flow of a liquid, particularly for feeding molten metal into the rotating mold of a centrifugal casting machine. Dec. 1, 1928.
664,925	Société d'Etudes et de Constructions Métallurgiques. Improvements to apparatus for charging shaft furnaces, especially blast furnaces. Mar. 7, 1928.
664,991	Heurtey & Co. Inspection hole. Mar. 14, 1928.
665,147	Cie. des Forges de Chatillon, Commentry et Neuves-Maison. Process and apparatus for utilizing the heat of slag. Dec. 6, 1928.
665,174	Hüttenwerke Tempelhof A. Meyer. Process for treating material containing tin, antimony, lead and copper in the combined state. Feb. 15, 1928.
665,181	The Surface Combustion Co. Process and apparatus for heat treatment. May 24, 1928.
664,787	H. W. Bundy. Process and apparatus for making finned tubing. Nov. 28, 1928.
664,799	Akt.-Ges. für Aluminothermische und Elektrische Schweissungen (Prof. Dr. Hans Goldschmidt Ingwer Block). Method and means for making a light and refractory mold between the ends of pieces of metal to be joined by casting iron at a suitable temperature around them. Nov. 28, 1928.
664,954	R. A. L. Seligmann, assignee of M. J. U. Marager. Process for autogenous welding, brazing, etc. Mar. 10, 1928.
664,977	La Soudure Autogène. Coating for electrodes suitable for arc welding. Mar. 12, 1928.
664,982	C. David. Economizer for autogenous welding. Mar. 13, 1928.
665,002	J. Fritz. Material to be used as solder and flux. Dec. 1, 1928.
664,750	Cie. Française pur l'Exploitation des Procédés Thomson-Houston. Improvements to arc welding machines, especially automatic ones. Nov. 20, 1928.
664,794	Metallgesellschaft Akt.-Ges. Process for eliminating halogen ions, particularly from salt solutions for the electrolytic separation of metals. Nov. 28, 1928.
664,803	Alloy Welding Processes, Ltd. Improvements to electrodes for electric arc welding. Nov. 28, 1928.
665,275	J. Schumacher. Process for refining and deoxidation of metals and product used in working this. Dec. 5, 1928.
665,487	S. A. des Forges, Usines et Fonderies de Gilly. Foundry crane. Dec. 10, 1928.
665,488	C. L. Ackermann. Lead alloys for bearings (Pb-Sb-Sn). Dec 10, 1928.
665,724	G. Patart and H. Nielsen. Improvements in the reduction of calcium carbonate and in the manufacture of carbides, also in the reduction of ores and the production of metals and alloys. Nov. 27, 1928.
665,254	W. Petri. Process for casting fine-mesh grids for electric storage batteries. Nov. 23, 1928.
665,313	F. S. A. Solére. Portable apparatus for electrodeposition. Mar. 19, 1928.
665,357	J. Laissus. Process for rendering corrosion-proof objects of copper or copper alloys. Mar. 22, 1928.
665,456	A. De Fries. Bolt press. Dec. 8, 1928.
665,663	Berkenhoff and Drebes Akt.-Ges. Multiple wire-drawing machine. Apr. 22, 1928.
665,416	A. Esau and C. Lorenz Akt.-Ges. Device for treating substances with high-frequency currents. Dec. 7, 1928.
665,417	A. Esau and C. Lorenz Akt.-Ges. Device permitting treatment of substances with high-frequency currents. Dec. 7, 1928.
665,422	L. Castets and E. Courret. Electric furnace. Dec. 6, 1928.
665,504	E. Bornand and H. A. Schaepfer. Electric furnace. Dec. 19, 1928.
665,651	Ternstedt Manufacturing Co. Bath and process for chromium plating. Dec. 13, 1928.

French Addition Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
34,662	E Giacchino. Process and apparatus for forging and roughing out iron and steel sections. Dec. 30, 1927. (Addition to No. 644,544.)
34,730	Aktiebolaget Svenska Kullager Fabriken. Improvement to coupling boxes for rolling mills. (2nd addition to No. 624,874.)

German Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
477,950	P. Trotzig, Magdeburg, Germany. Froth flotation process. Feb. 20, 1927.
478,026	J. A. Katzeneyer, Ellwood City, Pa. Process for rolling tubing. June 3, 1924.
478,027	T. E. Holmes, Glasgow, Scotland. Articulated coupling for rolling mills. Jan. 7, 1928.
477,973	International General Electric Co., Inc., New York, N. Y. Process for the continuous extrusion of a metal sheath about a core. Aug. 14, 1925.
478,028	Rheinische Metallwaren und Mashinenfabrik, Düsseldorf-Derendorf, Germany. Process for working down hollow metal bodies. July 17, 1927.
477,765	Maschinenfabrik Fr. W. Schnutz, Weidenau a.d. Sieg, Germany. Machining for straightening and polishing sheets. Aug. 27, 1928.
470,878	H. Junkers, Dessau, Germany. Machine for packing sheets. (Addition to No. 477,153.) Aug. 12, 1925, in Sweden July 24, 1925.
477,760	W. Erfurth, Altona, Germany. Process for drawing shells of pure zinc. July 4, 1928.
477,888	Bergbau und Hütten Akt.-Ges., Friedrichshütte, Heidorf, Germany. Process for roasting or sintering fine ore, carbonates or similar materials with the aid of electric current. May 18, 1926.
477,776	R. Müller, Jr., Essen, Germany. Muffle furnace with flameless combustion. June 12, 1926.
478,085	H. Schaffert, Halle a.d.S., Germany. Discharging device for annealing furnaces with rotating heating drums. Mar. 24 1928.
478,092	Feuer und Luft Ges. für Feuerungs und Luftungsanlagen m. b. H., Köln-Ehrenfeld, Germany. Jolting device for mold boards, placed on the work table of the molding machine. May 3, 1927.
477,988	H. Müller, Siegen, Westfalen, Germany. Annular spray nozzle for applying blacking to molds. May 15, 1928.
477,989	G. Samm, Vorhalle, Westfalen, Germany. Sand mixing machine. Sept. 1, 1927.
477,990	G. Samm, Vorhalle, Westfalen, Germany. Sand mixing machine. (Addition to No. 477,989.) May 27, 1928.
477,991	R. Spolders, Duisburg-Wanhainerort, Germany. Method of, and device for, attaching models to mold boards. Oct. 6, 1926.
477,992	C. Vaughan and F. H. Adams, Ltd., Birmingham, England. Die-casting mold with yielding parts inside the mold which are forced outward under the pressure of the molten metal. Oct. 21, 1927, in Great Britain Sept. 10, 1927.
478,075	R. Müller, Berlin-Wilmersdorf, Germany. Process for making aluminum-silicon alloys. July 17, 1925.
478,183	A. C. Houdijk, The Hague, Netherlands. Current washing apparatus with horizontal pipe system. Dec. 12, 1926, in Netherlands Nov. 29, 1926.
478,184	Head, Wrightson & Co., Ltd., Thornaby-on-Tees, England, and H. Clark, London, England. Drive for classifying and dewatering screens. Apr. 8, 1926.
478,270	F. Osenberg, Solingen, Germany. Device for changing the mandrels of Pilger rolling mills. July 24, 1928.
478,474	Drahtindustrie Peter Darmstatdt and Co. G. m. b. H., Frankfurt a.M., Germany. Multiple wire-drawing machine for drawing the thinnest wires. Mar. 17, 1927.
478,328	Stahlwerk Westig, Unna i.W., Germany. Process for hot drawing steel wire. Dec. 30, 1927.

Patent No.	Patentee, Subject of Invention, and Filing Date
478,129	Siegener Akt.-Ges. für Eisenkonstruktion, Brückenbau und Verzinkerei, Geisweid, Kr. Siegen i.W., Germany. Raisable and lowerable closure hood for shaft furnaces, especially roasting furnaces. Dec. 25, 1927.
478,379	Witkowitzer Bergbau- und Eisenhütten Gewerkschaft and C. Salat, Witkowitz Mähren, Germany. Powdered coal firing for furnaces. Jan. 25, 1924.
478,390	Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. Method of cooling annealed material under a cooling hood outside the hearth annealing furnace. Mar. 18, 1927.
478,283	New Process Multi Castings Co., New York, N. Y. Molding machine. Jan. 31, 1926, in the United States May 29, 1925.
478,216	E. O. Beardsley and W. F. Piper, Chicago, Ill. Sand slinging machine for filling molds. May 14, 1925.
478,217	N. Littell, New York, N. Y. Sand slinging machine. Mar. 12, 1927.
478,318	Gewerkschaft Wallram, Abteilung Metallwerke, Essen, a.d. Ruhr, Germany. Method of casting sparking stones of heavy metal carbides. Jan. 3, 1926.
478,363	Langbein-Pfanhauser-Werke Akt.-Ges., Leipzig, Germany. Conveying long, thin bulk material through galvanizing baths. Nov. 4, 1927.
478,643	E. Bender, Beuthen, O.S., Germany, and Bender & Främbs, Hagen i.W., Germany. Grid work for Cowper stoves or regenerator chambers. Jan. 13, 1927.
478,563	Höganäs-Billesholms Aktiebolag, Höganäs, Sweden. Process for making sponge iron. Dec. 3, 1927.
478,544	Th. Goldschmidt Akt.-Ges., Essen a.d. Ruhr, Germany. Process for welding together scrap in bundles. Sept. 3, 1925.
478,811	M. Füchsel, Nowawes, near Berlin, Germany. Method of electrically welding metal parts to lamellar bodies. June 27, 1926.
478,849	M. Felder, Sennelager, Germany. Cupola with auxiliary hearth. May 23, 1926.
478,887	International De Lavaud Manufacturing Co., Ltd., Toronto, Ont. Device for centrifugal casting molds. Oct. 25, 1927, in the United States Nov. 23, 1926.
478,511	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. Process and apparatus for obtaining deposition products having the same physical properties by electro-chemical processes. Mar. 7, 1928.
478,769	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. Chromium plating process, especially for large objects. July 21, 1927, in the United States July 27, 1926.
478,770	F. von Wurstemberger, Zürich, Switzerland. Method of maintaining the purity of electrolytic baths, especially nickel baths. Dec. 15, 1927, in Switzerland Nov. 25, 1927.
478,901	J. Savage, Weston Point, near Runcorn, Chester, England. Portable apparatus for degreasing metal and other objects. Sept. 22, 1926.
478,902	Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. Process for protecting metallic coatings on metal bodies by means of an oil coating and device for working this process. May 8, 1927.
478,398	B. Beck, Magdeburg, Germany. Charging device for shaft furnaces. Nov. 29, 1927.
478,532	E. Knöringer and K. Wolsky, Wülfrath, Germany. Charging device for shaft furnaces. Apr. 22, 1928.
478,839	Süddeutsche Waggonfabrik G. m. b. H. & Co. Kamm-Ges., Munich, Germany. Charging device for shaft furnaces. July 15, 1927.
479,261	Hydraulik G. m. b. H., Duisburg, Germany. Tubing extrusion press. Feb. 6, 1926.
479,222	H. Junkers, Dessau, Germany. Device for packing sheets. (Addition to No. 477,153). Aug. 12, 1925, in Sweden July 24, 1925.
478,944	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. Method of making welded heat exchangers. Feb. 8, 1925.
479,147	Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. Method and appliance for the mechanical charging of electric furnaces. Nov. 24, 1925.
478,990	"Gafag" Gasfeuerungs-Ges., and Dipl. Ing. Wentzel & Cie., Frankfurt a.M., Germany. Method of operating gas-fired annealing and forging furnaces, the gas and air being preheated in a recuperator. Jan. 5, 1924.
479,336	Gebr. Siemens & Co., Berlin-Lichtenberg, Germany. Process for making carbon electrodes having a metallic armor. Nov. 6, 1923.
479,036	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. Die-casting machine for aluminum alloy castings. Aug. 31, 1926.
479,089	E. Will, Hamburg, Germany. Die-casting machine. Apr. 9 1926.

Italian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
260,900	Compagnia Generale di Electricita, Milan, Italy. Improvements in methods for the carburization of metals. Aug. 25, 1927, in the United States Aug. 26, 1926 (in the names of G. W. Hegel and G. R. Brophy).
260,574	R. De Robillard, Tananarive, Madagascar. Device for treating graphite and other minerals by flotation. Aug. 4, 1927, in France Aug. 7, 1926.
260,904	The Granular Iron Co., New York, N. Y., assignee of J. W. Hornsey. Process and apparatus for reducing metallic oxides. Aug. 24, 1927, in the United States Sept. 8, 1926.
260,905	The Granular Iron Co., New York, N. Y., assignee of J. W. Hornsey. Process for reducing metals. Aug. 24, 1927, in the United States Sept. 8, 1926.
260,571	W. Koehler, Cleveland, Ohio. Process for producing metallic magnesium and apparatus therefor. Aug. 2, 1927.
260,907	Siemens Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. System of heat treating metals in a closed chamber. Aug. 25, 1927, in Germany Aug. 27, 1926.
260,811	F. Wüst, of Germany. Furnace for melting low-carbon iron. Aug. 5, 1927, in Germany Aug. 6, 1926.
261,043	E. Piwowarsky and P. Oberhoffer, Düsseldorf-Grafenberg, Germany. Process for making cast steel, suitable for utensils. (Addition to No. 257,060.) Mar. 17, 1927, in Germany July 15, 1926.
260,888	Anaconda Mining Co., New York, N. Y. Process and device for recovering metals. Aug. 29, 1926.
260,944	Fagersta Bruks Aktiebolag, Fagersta, Sweden. Improvements in the manufacture of hollow drill rods. Aug. 24, 1927, in Sweden Oct. 9, 1926.
260,869	E. Giacchino, Turin, Italy. Improvement in electric forging machines. Aug. 23, 1927.
260,984	Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. Process for coating a body with platinum. Aug. 22, 1927.
260,582	Zähner & Schiess & Co., St. Gall, Switzerland. Method of forming lead coatings. July 30, 1927, in Germany Aug. 30, 1926 (in the name of "Suchox" Akt.-Ges. Electrochemische Fabrik für Metallhüttenprodukte).
260,747	A. H. Coplan, Hull, Que. Improvements to cupolas. July 30, 1927.
260,639	"Ilva" Alti Forni e Acciaierie d'Italia, Genoa, Italy. Continuous heat treating furnace. Oct. 6, 1927.
260,703	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. Electric furnace. July 30, 1927, in Germany Aug. 9, 1926.
260,906	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. Furnace for heat treating strip, wire and the like. Aug. 25, 1927, in Germany Aug. 26, 1926.
260,617	Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. Improvements in electric induction furnaces. July 11, 1927, in the United States July 27, 1927 (in the name of P. H. Brace.)
260,622	F. Bischitsky, Aussig, Czechoslovakia. Process for recovering metals such as tin, lead, copper, antimony, bismuth and zinc from alloys and scrap metal. May 28, 1927.
261,153	H. Colloseus. Process for the separation of metallic chromium by electrolysis. Aug. 12, 1927.
261,082	A. Cortese, Genoa, Italy. Chemical process for the recovery of metallic tin from scrap by means of pure aluminum and its alloys. Aug. 23, 1927.
261,377	E. Cumberland, Kingston Hill, Surrey, England. Method and means for preventing corrosion of metals. May 21, 1927.
261,127	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. Magnesium alloy for the pistons of internal-combustion engines. Aug. 13, 1927, in Germany Aug. 13, 1926.
261,340	T. E. G. Gustafsson, Stockholm, Sweden. Process for producing metals in the electric furnace. Sept. 24, 1927, in Sweden Sept. 27, 1926.
261,325	Nybergs Grufaktiebolag, Stockholm, Sweden. Process for roasting and reducing ores. Apr. 8, 1927.
261,511	H. E. Sundberg, Stockholm, Sweden. Process for the electrodeposition of copper. July 12, 1927.
261,337	Wheeling Stamping Co., Wheeling, W. Va. Process and apparatus for casting metals. July 18, 1927.
261,343	Aluminum Die-Casting Corp., Garwood, N. J. Improvements in die-casting machines. Jan. 24, 1927, in the United States Sept. 1, 1926 (in the name of G. W. Bungay).
261,465	E. Cerliani, Pavia, Italy. Wire-drawing die. Apr. 7, 1927.
261,503	Parker Rust Proof Co., Detroit, Mich. Process for producing a rust-preventive coating on iron objects. May 6, 1927, in the United States May 10, 1926 (in the names of M. Green and H. H. Willard).
261,491	Metallogen G. m. b. H., Berlin- Neukölн, Germany. Process for making metallic coatings. June 5, 1926. (Addition to No. 259,411, filed May 28, 1926.)
261,492	Metallogen G. m. b. H., Berlin-Neukölln, Germany. Process for making metallic coatings. June 5, 1926. (2nd Addition to No. 259,411, filed May 28, 1926.)
261,112	Carlo Wedekind & C., Palermo, Italy. Process for preserving metallic bodies against corrosive agencies. Apr. 30, 1928. (1st addition to No. 251,489, filed Oct. 31, 1927.)
261,229	Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. Insert for high-frequency furnaces. Aug. 18, 1927, in Germany Aug. 9, 1926.

Personals

C. P. Taylor has accepted a new position as chief chemist for the Western Cartridge Company, East Alton, Ill.

Arthur W. Gray, Ph.D., has joined the staff of the Brown Instrument Company as associate director of research. He will be engaged mainly in the development of scientific and industrial instruments. For this work Dr. Gray is well fitted by his long training and experience. He established the Thermal Expansion Laboratory of the Bureau of Standards and originated important methods and apparatus that are still in use there.

Dr. F. C. Frary, director of research, Aluminum Co. of America, was elected president of the American Electrochemical Society at its annual meeting in Toronto on May 29th.

Stephen S. Tuthill resigned as Secretary of the American Zinc Institute on August 1st.

N. K. B. Patch, Secretary of the Lumen Bearing Co., Buffalo, N. Y., has been elected First Vice-President of the American Foundrymen's Association.

H. J. French, until recently senior metallurgist of the Bureau of Standards, U. S. Department of Commerce, is now associated with the development and research department of the International Nickel Company and located at their research laboratory at Bayonne, N. J. Mr. French has been active on several committees of the A. S. S. T. and has contributed many valuable technical papers before conventions and meetings of the society.

George **H. Bierman,** formerly metallurgist with the White Motor Co. of Cleveland, has recently accepted the position of physical metallurgist in the technical research department of the International Combustion Engineering Corporation, 191 Doremus Ave., Newark, N. J.

John **H. Nelson,** for 11 years chief metallurgist for the Wyman-Gordon Co., has been appointed manager of the Worcester, Mass., division of that company.

H. G. **Batcheller,** Vice-President of the Ludlum Steel Co., and President of Krupp Nirosta Co., recently sailed for Germany.

The Research Laboratory of the American Sheet & Tin Plate Company, Pittsburgh, Pa., announces the following additions to its staff: C. P. Larrabee, chemist and H. E. Romine, metallurgist.

C. C. Willits, formerly with the Central Alloy Steel Corporation, has accepted a position with the Standard Tin Plate Company, Cannonsburg, Pa.

F. J. Griffith, chairman of the board of the Central Alloy Steel Corporation, Massillon, O., recently returned from a European trip on which he studied the alloy steel industry.

Robert C. Good has been appointed metallurgical engineer for the Electro Metallurgical Sales Corporation, New York. His headquarters will be 816 Oliver Bldg., Pittsburgh.

Harold D. Smith, for many years the district representative of the Colonial Steel Co., has resigned to accept a position as district representative of the Cyclops Steel Co., in the Connecticut territory.

Dr. Adolph Fry, inventor of the nitriding process, who holds the important position of Research Metallurgist, Krupp Steel Company, will attend the Iron & Steel Exposition in Cleveland in September.

Carl Kuettner, formerly metallurgist of the Central Alloy Steel Corp., Canton, Ohio, left for Europe. He will enter the Technische Hochschule of Breslau in the fall to continue his studies in preparation to taking his doctor's degree.

Industrial Notes

Thompson Products, Inc., manufacturers of valves and other automobile parts, are establishing a research division under the name Thompson Research, Inc., at 2209 Ashland Rd., Cleveland. There will be a laboratory combining physical, chemical, metallography and automobile testing.

The Duraloy Co., Pittsburgh, has moved its Chicago office from 8253 Laflin St. to 608 South Dearborn St.

Quigley Furnace Specialties Co., manufacturers of high-temperature cements and protective coatings, has recently moved from 26 Cortlandt St. to 56 West 45 St., New York.

The American Metallurgical Corp. announces that its corporate name has been changed to American Electric Furnace Co. It is stated that the personnel of the organization, its business policies and standards remain unchanged.

The Central Alloy Steel Corp. announces the appointment of S. H. Truitt as district sales manager at Philadelphia.

Automatic Temperature Control Co., 34 E. Logan St., Philadelphia, has established a permanent exhibit of various types of control apparatus, wired for practical demonstration. This has been established so prospective customers may better visualize this company's control equipment and its possibilities.

The New York district office of the Central Alloy Steel Corp. has been moved from the Pershing Square Bldg. to 230 Park Ave., New York. The Detroit office has been moved to the Fisher Bldg.

The Chrobaltic Tool Company announces the completion of its new brick and steel addition to Number 2 foundry at Michigan City, Indiana, making a substantial increase in capacity.

Cleveland Meeting Program

The Iron and Steel Division of the American Society of Mechanical Engineers will hold their annual fall meeting in Cleveland, the week of September 9th, during the National Metal Congress. This Division of the Mechanical Engineers has made tremendous growth in the last few years since its organization, and now numbers thousands of production, mechanical and combustion engineers.

During the National Metal Congress the National Metal Exposition will be held in Cleveland's mammoth public auditorium with over 250 exhibitors devoting their exhibits to a complete line of the metal industry and with a complete display of steel mill equipment and supplies.

The papers to be presented by the A. S. M. E. are as follows:

DEVELOPMENTS IN BLAST FURNACE DESIGN AND PRACTICE—By Arthur G. McKee, Cleveland, Ohio.

ORE HANDLING BRIDGES—By Alexander C. Brown, President, Industrial Brown Hoist Corporation, Cleveland, Ohio.

OIL ELECTRIC LOCOMOTIVES IN STEEL MILL TRANSPORTATION—By N. L. Garrison, Assistant Manager, Locomotive Department, Ingersoll-Rand Company, New York City.

NON-DESTRUCTIVE TESTS OF WELDS—By Elmer A. Sperry, President, American Society of Mechanical Engineers (A. W. S.)

FOREIGN PRACTICE IN WELDING BOILER TUBES AND DRUMS—By George A. Orrok, Consulting Engineer, New York City.

AUTOMATIC ARC WELDING OF THIN SHEETS—By W. L. Warner, Industrial Heating and Welding, Engr. Dept., General Electric Co., Schenectady, N. Y.

ALLOY STEELS IN IRON AND STEEL MILL EQUIPMENT—By M. J. R. Morris, Central Alloy Steel Corporation, Massillon, Ohio.

EVOLUTION OF DRIVES FOR MILL TABLE ROLLERS—By K. W. Feller, Branch Manager, Schloemann Engineering Corporation, Pittsburgh, Pa.

DISTRIBUTION OF HEAT IN COMBUSTION FURNACES—By M. H. Mawhinney, Electric Furnace Company, Salem, Ohio.

ADVANTAGES OF PRODUCER GAS AS A FUEL COMPARED WITH OTHER FORMS OF FUEL—By Victor Windett, Wellman, Seaver, Morgan Company, Cleveland, Ohio.

POWDERED COAL CUPOLA—By D. H. Meloche, American Radiator Company, New York City.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment, should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department.*—EDITOR.

Wrought Iron.—*The Wrought Iron Record*, a new publication published by the Wrought Iron Research Association, is issued "to make known the virtues of genuine wrought iron, to inform the public of the forms in which it can be obtained, and to present examples of its enduring values in use." Two issues have now appeared. Wrought Iron Research Association, Union Bank Building, Pittsburgh, Pa.

Hump Method.—Piece No. 19 is entitled "Hardening Better Tools with Less Effort" and illustrates the use of the Hump method for the hardening of carbon-steel tools by Deere & Co. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

Blow-Pipes and Torches.—Leaflet briefly describes jewel torches and oxy-air-gas blow-pipes for working Pyrex and quartz glass; for soldering, brazing, lead burning; for making platinum and gold jewelry; for melting dental alloys, platinum, etc. Hoke, Inc., 22 Albany St., New York, N. Y.

Hardening High Speed Steel.—Bulletin 1012 covers the Sentry Diamond Block method of hardening High Speed Steel. The Sentry Company, Taunton, Mass.

Arc Welding.—The very wide range of uses of electric arc welding in the maintenance field is pictorially shown in the publication D. M. F. 5156. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The Laboratory.—Vol. 2, No. 3 of the *Laboratory* contains a brief sketch entitled "Charles M. Hall and Aluminum." This is illustrated with a cut of the Aluminum Memorial to Charles Martin Hall at Oberlin College. Another sketch illustrates the first specimens of aluminum produced by Hall. The balance of this publication covers instruments and apparatus of the Fisher Scientific Company. Fisher Scientific Company, 711 Forbes Street, Pittsburgh, Pa.

Oxy-Acetylene Tips.—The June issue of this publication contains a number of articles on various applications of welding. Linde Air Products Co., 30 East 42nd Street, New York, N. Y.

Nickel Steel.—Nickel Steel Data No. 14 is a reprint from the Transactions of the American Society of Mechanical Engineers entitled "The Manufacture of Nickel Steel Plate." It deals with the manufacture, rolling and inspection of steels containing between 2 and 3% of nickel and which are used in boiler construction. The physical properties of the metal are first discussed, following which details are given of its manufacture, beginning with the ingot phase and proceeding then step by step through stripping and reheating, rolling, flattening, inspecting and shearing, and finally testing. The International Nickel Company, 67 Wall Street, New York, N. Y.

Electric Melting Furnace.—Bulletin GK is reprinted from a paper presented at the convention of the American Foundrymen's Association. It describes the operation of a 1½-ton per hour "Lectromelt furnace." Pittsburgh Electric Furnace Corporation, P. O. Box 1125, Pittsburgh, Pa.

Allegheny Metal.—Bulletin A describes in detail the properties of this chromium alloy in regard to resistance to several forms of corrosion and in regard to its tensile properties. Allegheny Steel Co., Brackenridge, Pa.

Carboloy.—Form C-10 gives briefly the properties of Carboloy. Information on special applications is given. Carboloy Company, Inc., 350 Madison Ave., New York, N. Y.

Arco Metal Pipe.—This bulletin gives information on this new ni-chrome alloy iron, cast by a process which gives the resultant product greater ductility and tensile strength, and also, due to the close grain structure, greater corrosion- and erosion-resisting qualities than ordinary gray cast iron. Form No. 9012. American Radiator Company, 40 West 40th St., New York, N. Y.

Illium.—A recent leaflet on Illium, a complex alloy based on the nickel-copper-chromium ternary system, gives the physical characteristics of Illium, "G," also the results of corrosion tests. Burgess-Parr Company, Moline, Illinois.

Testing Machines.—A catalogue in English covers testing machines for determining: tensile strength, Brinell hardness, machinability, fatigue strength and spring strength. Losenhausenwerk, Düsseldorf-Grafenberg, Germany.

Welding Rod.—A booklet entitled "High Test Welding Rod" describes an improved welding rod for making stronger welds in steel. Oxweld Acetylene Company, 30 East 42nd St., New York, N. Y.

Optical Pyrometer.—Leaflet describes a new type optical pyrometer. The principle of operation is illustrated. Pyrometer Instrument Company, 50 Howard Street, New York, N. Y.

Plating Temperature Control.—The Chromium-Plating Temperature Controller is briefly described and illustrated in Leaflet DMF-549. The Foxboro Company, Foxboro, Mass.

Pickling Tank Temperature Control.—The advantages gained by the use of pickling tank temperature control are briefly enumerated in a leaflet entitled "What More Can Be Expected?" Foxboro Company, Foxboro, Mass.

Dilatometer.—Bulletin No. 2904 points out that the dilatometer speeds up production in precision heat treatment. Stanley P. Rockwell Company, 66 Trumbull St., Hartford, Conn.

Steel Castings.—Leaflet illustrates light steel castings made by the Lebanon Steel Foundry. Lebanon Steel Foundry, Lebanon, Pa.

Abrasives.—Folder entitled "Artificial Abrasives, Their History and Development." Norton Company, Worcester, Mass.

Sprayed Metal Coatings.—Folder describes how molten metal is sprayed on metal surfaces and the advantages obtained thereby. Metals Coating Co. of America, Philadelphia, Pa.

Vitreous Enameling.—Control methods and laboratory practices used by the Ferro Enameling Co. are described and illustrated in a recently published booklet. Ferro Enameling Company, Cleveland, Ohio.

Pickling Tank Temperature Control.—Folder points out the advantages of using automatic temperature control for standardized pickling. Weaver Bros. Co., Adrian, Mich.

Heating Galvanizing Tanks.—Bulletin GEA-1102 illustrates electric heating equipment to be used in connection with hot galvanizing tanks. General Electric Co., Schenectady, N. Y.

Electric Heating Furnaces.—"From Steel Balls to Oil Stills" is the title of a booklet describing electric heating furnaces. Electric Furnace Co., Salem, Ohio.

Copper Bearing Steel Pipe.—Bulletin discusses the use of copper-bearing steel pipe and shows comparative results of exposure of copper-bearing steel and steel without copper. National Tube Company, Pittsburgh, Pa.

Strain Gauge.—A booklet describes the Whittemore Strain Gauge in detail, also includes instructions for use. Southwark Foundry & Machine Company, 400 Washington Ave., Philadelphia, Pa.

Laboratory.—Vol. Two, No. Two contains as the feature article "Herbert Hoover—Scientist." A number of short articles cover new instruments. Fisher Scientific Company, 711 Forbes St., Pittsburgh, Pa.

Chrome Plating.—Bulletin 376 describes an automatic temperature control for holding temperature constantly uniform, insuring the most efficient chrome deposit. Bristol Company, Waterbury, Conn.

Automatic Control Valves.—Catalog No. 2000 describes automatic electric motor operated and magnet type control valves. Bristol Company, Waterbury, Conn.

Moisture Meter.—Bulletin No. 975 describes a meter for determining the moisture content of wood quickly and without destroying the sample. C. J. Tagliabue Mfg. Co., 18 Thirty-third St., Brooklyn, N. Y.

Testing Machine.—The "Evolution of the Testing Machine" gives a history of the Riehle Bros. Testing Machine Company, 1424 N. 9th St., Philadelphia, Pa.

Chemist-Analyst.—The March issue contains many articles of interest to analytical chemists. J. T. Baker Chemical Co., Phillipsburg, N. J.

Gas Analysis.—Bulletin describes the thermal conductivity method of gas analysis and apparatus for CO_2 and SO_2. Charles Engelhard, Inc., 90 Chestnut St., Newark, N. J.

Testing Machines.—Bulletin E shows various types of ductility testing machines, extensometers and dynamometers. Tinius Olsen Testing Machine Company, 500 N. 12th St., Philadelphia, Pa.

Maintenance Data Book.—This is a 93-page bound volume, carefully indexed, giving extensive information and data on a large variety of industrial maintenance problems. Corrosion and wear-resisting paints, enamels, concrete coverings, etc., are mentioned in considerable detail. Methods of cleaning various surfaces are also included. Truscon Laboratories, Detroit, Mich.

High Temperature Cement.—Hytempite, a refractory cement for boiler settings, metallurgical furnaces and other industrial furnaces, is discussed in a recent 8-page bulletin. Methods of applying the product, both in new construction and in making repairs, are mentioned. Quigley Furnace Specialties Co., 26 Cortlandt St., New York, N. Y.

Magnetic Separation.—A new bulletin is devoted to the separation of magnetic impurities from flour, cereals, grain, cottonseed, pulverized coal, lime and other bulk materials. The bulletin illustrates and describes the several different modifications for specific applications, including a machine for eliminating dust in handling finely pulverized material. Magnetic Mfg. Co., Milwaukee, Wis.

Enduro K A 2 Steel.—A new type of stainless steel is the subject of a new bulletin. In addition to a large number of illustrations showing the numerous applications of this material, the booklet contains information on the chemical and physical properties of this material, its physical properties at high temperatures, its corrosion resistance, and information on its fabrication. Booklet can be obtained for Central Alloy Steel Corporation, Massillon, Ohio; Ludlum Steel Company, Watervliet, N. Y.; The Babcock & Wilcox Tube Company, New York, N. Y.

Molybdenum in 1928.—This 61-page booklet contains only articles, extracts and abstracts from technical publications. Articles are presented on the following subjects: Molybdenum in Aircraft; Molybdenum in the Automobile; in Bearings; in Steel Castings; in Corrosion Resisting and High Temperature Alloys; and a section of extracts from foreign publications. Climax Molybdenum Company, 61 Broadway, New York, N. Y.